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THE AMERICAN NATURALIST

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IN THEIR WIDEST SENSE

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Erratum.

In the article by F. C. Baker, pp. 665-679, Figs. 5 and 9 should be transposed.

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THE HABITS OF THE STRIPED MEADOW CRICKET (*ŒCANTHUS FASCIATUS* FITCH).

JOSEPH L. HANCOCK.

IN uncultivated wastes the common horse-weed (*Leptilon canadense* L.) often takes possession of the soil and flourishes most luxuriantly. Owing to its rapid growth, it not infrequently overshadows the neighboring clover, wormwood, knotweed, daisy fleabane, and other forms of plants which may happen to live where its society conflicts. There are many interesting features in the miniature forests of weeds, not the least of which is the insect life they harbor. In the last of August the weed first mentioned commonly attains a maximum height in sandy soil of from four to six feet, and it is at this period that it seemingly furnishes an ideal environment for the striped cricket *Œcanthus fasciatus* Fitch.[1]

My experience with this cricket (see Fig. 2), which is here related, is principally drawn from observations made at Lakeside, Michigan, during the month of August, the last day of September, and the first two days in October, 1904. Further studies

[1] This cricket is commonly classed among the tree crickets, but it never or rarely lives on trees.

of its habits were carried out on numerous live individuals which I transported to my home in Chicago.

I have found this insect living singly, or from one to four together, upon the horse-weed, the females predominating during August. It is found more often on the main central stem, from eighteen inches to two and a half feet from the top, attracted there doubtless for the purpose of courtship and oviposition. Here it exhibits exquisite protective resemblance. The body of the insect is colored pale green, but the legs, antennæ, maxillary palpi, head, thorax, cerci, ovipositor, the ventral aspect of the thorax and abdomen, are very dark, though the color is somewhat variable. It is a delicate soft bodied insect, with exceptionally long antennæ. One of its favorite habits is closely to grasp the green main stem of its chosen plant with its body resting upside down. When disturbed, its first impulse usually is to jump to the ground, where its black legs, blending with the background of earth, are invisible, while the top of the body being green, now appears from above like a small blade of grass. If the insect is again molested while on the ground, it jumps quickly here and there in a spasmodic manner, then catching hold of some herbage climbs upon it. After waiting sufficiently long for danger to pass, the cricket eventually springs from one small plant to another until it again finds the main stem of the horse-weed. It then climbs up to take a position similar to that which it formerly occupied. One may often find it at rest, with its legs extended nearly straight out behind the body; or it may appear on the flowers feeding. After a dry spell of weather in August, the older weeds, often selected as a residence by the crickets, present a series of dead brownish leaves below, that extend from the ground a third or more the length of the plants upwards. Because of the existence of these dead leaves and shadows, the darker parts as well as the light coloring on these insects serve as excellent protection. Moreover, as they rest on the main stem, among the maze of leaves they enjoy complete immunity from their grosser enemies. Later in the season the habits undergo some modification incident to the change in the vegetation. For instance, on September thirtieth, I visited the horse-weed patch which furnished the theme of the above narra-

tion, to find that many of the weeds, while still standing, had turned brown and were dead. There were very few crickets to be found at the point where they had been so common before. After a long search a number were located in quarters somewhat different from those in which I had previously found them. They had taken up positions near the ground. To enumerate, I discovered one female hiding ten inches above the earth, within a folded dead leaf of a ground cherry. Close by was a male on a green leaf of the same plant. Immediately following these observations, I found two more males and a female on the light, yellowish green leaves of another of these plants. Similarly, a pair which were almost invisible were crouched among the leaves and seed receptacles of a Potentilla. On October first, among some wild blackberry bushes, I noted a number of these crickets of both sexes walking about on the upper surface of the leaves. The slightest motion on my part caused them to seek safety by darting around the side margins of the leaves, disappearing underneath, or they would jump below. Here I found two males near together clinging on upside down, each hiding within a curled leaflet of the blackberry. A stem of one of these plants which I found here, shown in the reproduced photograph (Fig. 1, *a*), shows ten punctures made by the ovipositor of *fasciatus*. The scarring of the plant in this way did not appreciably affect the health of the branch, the leaves of which were fresh and green. The same day I located a number of rather large plants of the golden-rod, the stems of which were used by this œcanthid for depositing her eggs. The points selected for this purpose were often situated half way down the main stem. Here the darkened scar areas can be recognized on the green stems where a number may be found lying in close proximity. The holes which are near together take the form of vertical continuous lines of varying length, or they appear dotting the surface irregularly, as shown in Figure 1, *b* and *c*. A broken longitudinal section of the golden-rod at the scarred places will show the eggs disposed in the manner represented in Figure 1, *d*. Or sometimes the eggs will be found missing, and instead of them there will be encountered a white larva which destroys the eggs. This grub tunnels through the central pith, feeding on it and leaving the stems hollow.

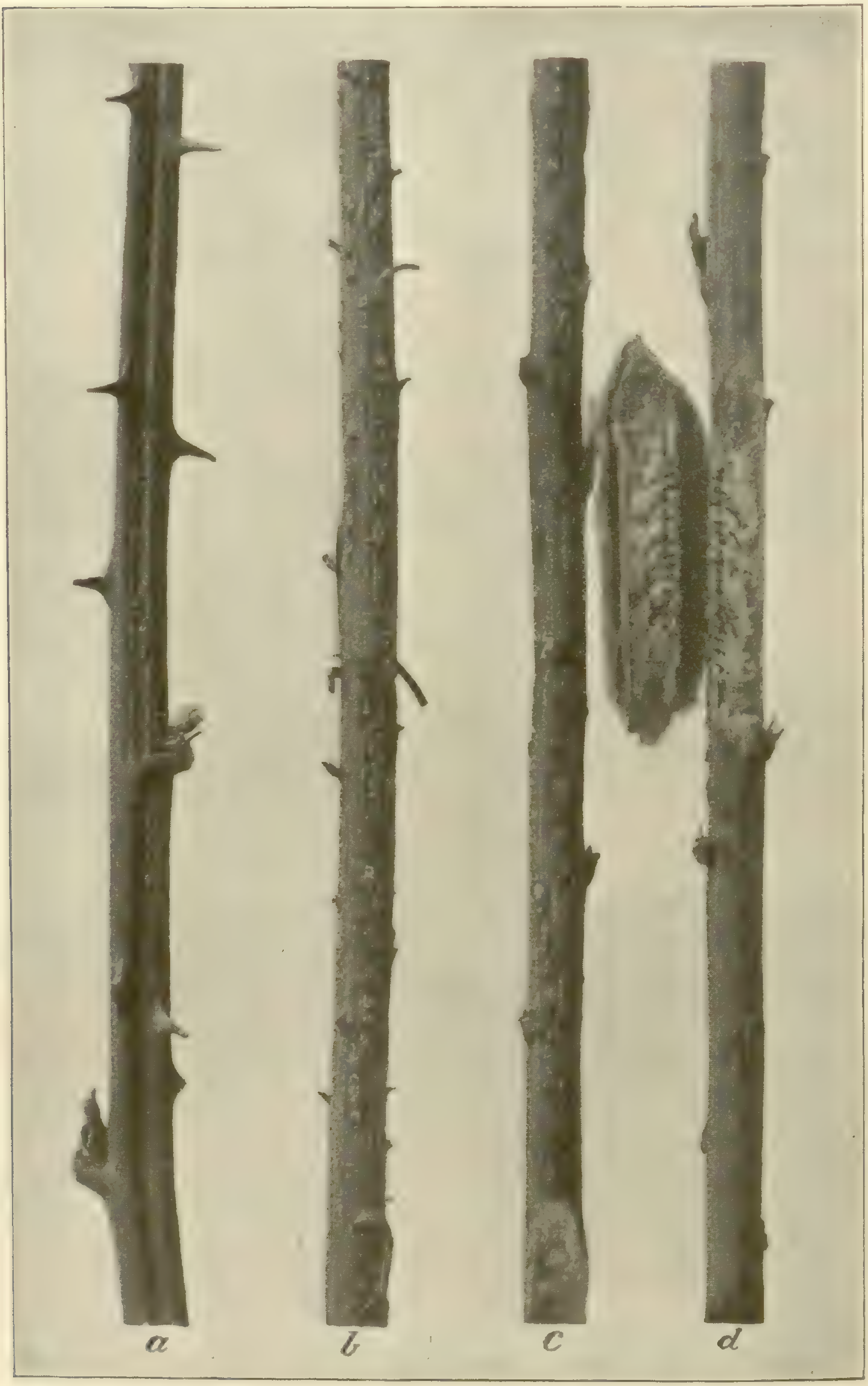


FIG. 1. — Stems of the blackberry, *a*, the horse-weed, *b*, and the golden-rod, *c* and *d*, which have been stripped of their leaves to clearly show the holes made by *Œcanthus fasciatus* during oviposition. A portion of the stem *d* has been removed longitudinally to show the eggs *in situ*. Photographed by the author. × 1½.

The Call Notes. — At 11.30 on the morning of September thirtieth, as the sun became overcast by clouds, I was treated to a pretty serenade by a host of males, which being hidden in a dense thicket of weeds gave out an exquisite example of their orchestration. Beyond this spot, in the open field planted with clover, but grown over with a mixed wild herbage, which included more or less scattering of the horse-weed, I heard the shrilling. After a little experience, one is led quite easily into the presence of these crickets by their song, as the following

Fig. 2. — *Œcanthus fasciatus.* The female is shown on the male's back in the attitude of devouring the plasmatic secretion within the thoracic gland located at the central part of the metanotum in the male. Photographed by the author, from living posed individuals, which were first subjected to partial asphyxiation with hydrocyanic gas. × 1½.

incident will prove. At 2.30 in the afternoon of October first, during the bright warm sunlight, I heard what seemed to be a chorus of *fasciatus* emanating from a source quite a distance off. From the open field where I stood, I gradually traced the trills to a corner of an adjoining unmowed field where the crickets appeared in abundance in a small wild blackberry patch. On near approach some of the songs ceased, but they soon commenced again when I stood perfectly quiet.

After nightfall, as well as in daytime, the high-pitched shrill notes of this œcanthid are uttered at irregular intervals, sounding not unlike the croaking of a frog or of a sparrow's notes when heard at a distance. They are not so monotonous as those of the large familiar black gryllid, or so resonant as the notes of the mole cricket. The concerts accompanying their little social gatherings may well be placed among the choicest of insect orchestrations.

Method of Alluring the Female during Courtship. — The male of this œcanthid possesses a remarkable mechanism for alluring the female during the period of courtship. He not only uses the pretty modified tegmina as an artifice in attracting her, but he also brings into operation a most peculiar thoracic device about to be described. In order to attract the female, the male, having approached within her sight, commences his advances by elevating his transparent tegmina to a nearly vertical position or right angle. Then separating them so that their surfaces rub together in and out, he produces a high-pitched shrilling for the female's benefit. She, in turn, being readily attracted by these notes moves towards him, and climbing on his back goes sufficiently far forward that her attention is further drawn to the little odd-shaped glandular fossa on the back of the thorax between the wings. Here she at once inserts her mouth to find a delicious potion secreted for her special needs, and which she devours ravenously, as depicted in Figure 2. The male in the meantime may or may not cease his singing, but while she is availing herself of the curious plasmatic drink, his tegmina are continually elevated, and his wings, which are folded at his sides, undergo a slight rhythmical motion in and out, lasting during the five to ten minutes she is usually content to stay. When she moves away he backs around towards her, again elevating his tegmina and repeating his song. Similarly affected by his overtures, and remembering the reward of sweets awaiting her return, she again mounts his body and proceeds to partake from his loving cup. These executions are repeated several times as a preliminary to the sexual act. Now the female is prepared by some subtile influence exerted by the male and she stays near by ready to again answer to his allurements. He

finally raises his tegmina in full display, and singing again to her she immediately reciprocates by mounting his body, but instead of indulging in his loving cup this time, she curves the end of her abdomen slightly downward, while at the same time he backs up and raising the end of the abdomen, conjugation is effected. The latter process lasts but a few seconds. After the sexual act, the female may be seen curving the end of her abdomen underneath forward, in order that she may clean the ovipositor with her mouth and include the genitalia in this toilet.

I have frequently observed the males in active combat over the possession of the female. As a result of these struggles, later on in the season, the males become decidedly dilapidated in appearance, the legs and wings having suffered more or less destruction as the result of the many contests for supremacy.

The Alluring Gland. — The function of the gland (Fig. 3), as above intimated, is solely for the purpose of alluring the female and it may be classed as a secondary sexual organ. It may be described as a moderately deep fossa, situated in the center of the metanotum of the thorax. It is bounded laterally by convex, rather obtusely rounded sides which converge and coalesce in front. Here anteriorly the border is flattened or depressed. On either side before the middle the lateral borders are strongly tumose, being provided with numerous sensitive hairs, the lateral borders behind the middle being continued into narrow convex ridges. The inner margins of the lateral borders are trisinuately excavated. Behind the gland lies the anterior concave border of the scutellum. Within the gland, occupying a point opposite the middle sinuation on either side (Fig. 3, *c*), is a flat brush of glandular hairs which project into the cavity obliquely. Just below, on either side, is another smaller brush (Fig. 3, *b*) composed of similar hairs which are directed inwards. The posterior half of the floor of the cavity is darker in color, being chitinized, and thus showing a line of demarcation separating it from the forward translucent portion. The posterior floor is, moreover, divided by a transverse sinuous ridge, and the inner third here behind (Fig. 3, *d*) is clothed with hairs.

An experiment on live crickets demonstrated that when the hairs on the surface of the swollen anterior lateral borders (Fig.

3, *a*) were stimulated by touching them with the point of a small artist's brush, or head of an insect pin, it gave rise to a responsive movement of the wing of the opposite side of the body. The same stimulus applied to both sides at the same time caused both wings to move or jerk simultaneously.

From these simple experiments I am led to infer that the motions of the wings witnessed during the sexual performances previously described are automatic in nature. They are caused

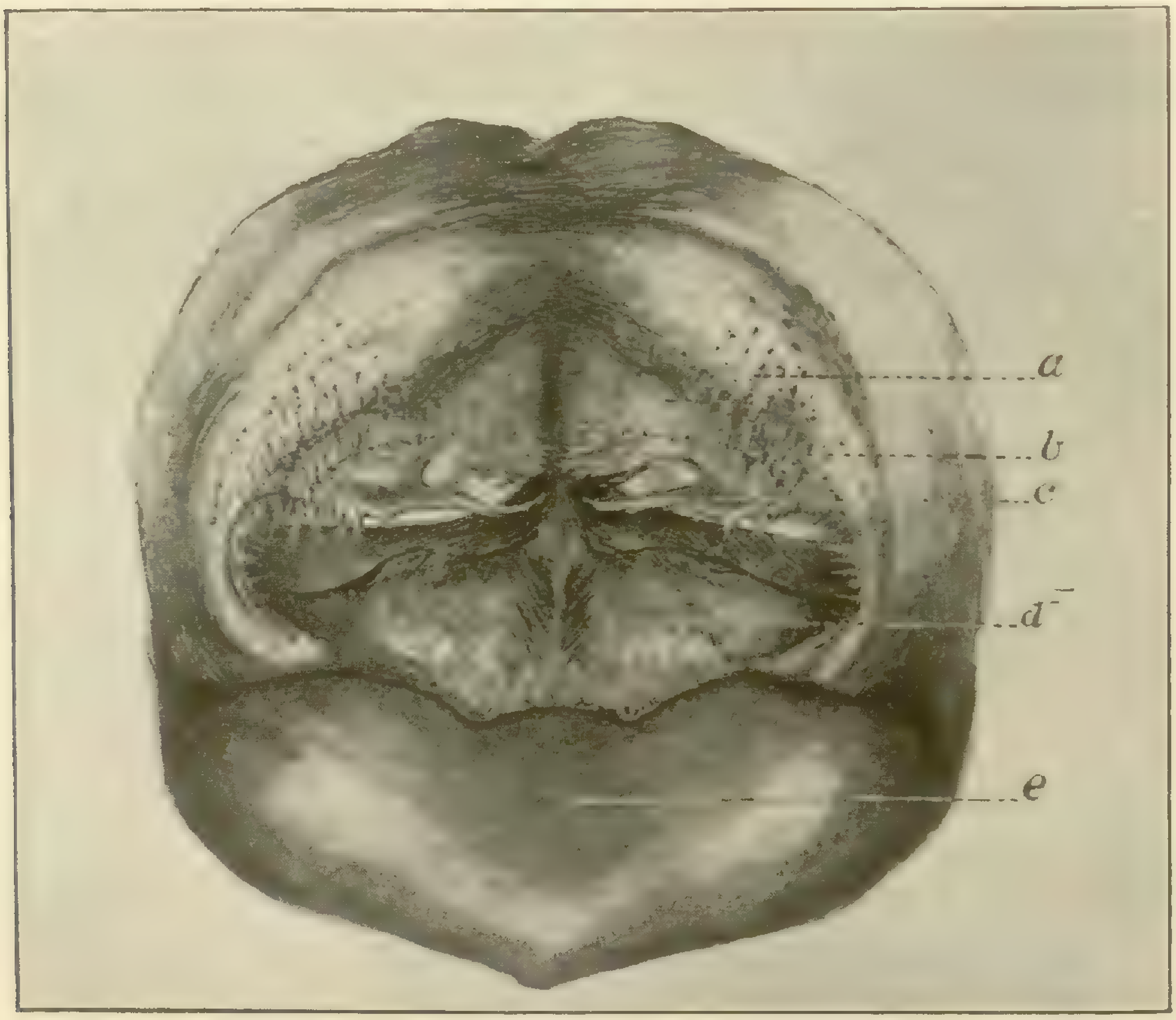


FIG. 3. — Enlarged view of the male alluring organ from above, in the scutum of *Œcanthus fasciatus*. The disposition of the sensitive hairs on the swollen lateral margins anteriorly are shown at *a*, the brush-like arrangement of the glandular hairs *b* and *c*, and the clothing of hairs on the posterior wall at *d*. Behind the organ or gland, lies the scutellum *e*. Drawn by the author. × 15.

by the female palpi touching the sensitive hairs above alluded to, during the time she is drinking.

When examining the male, one may often find, when raising the tegmina, a small plasmatic yellow droplet of the glandular secretion on the under side of the lower tegmina, opposite the position of the gland. This is an excessive fluid secreted from the glandular hairs. The gland fossa is often found filled

with the fluid, which seems to be partially soluble in water. When the gland becomes dried out, the evaporation of moisture causes the hairs, which are normally arranged in the flat rows before mentioned, to come together forming acute pencils. These pencils then take on the appearance of teeth, quite misleading to the casual observer. A small drop of water carefully placed in the cavity, while under the microscope, soon dispels this illusion by causing the hairs to spread out in the same way that a hair brush shows its individual hairs after a dried, sticky substance has been soaked out of it. My illustration (Fig. 3) presents a view of the entire gland after being treated with a drop of water.

From the foregoing statements regarding the sexual habits and the connection of this gland therewith, it may be of interest to note that the suggestion made by Blatchley (*Orthoptera of Indiana*, p. 452), that during the mating of this species the female removes the semen from the glands whose openings are intimated to be beneath the tegmina of the male, and that she then fertilizes her ova with the secretion there obtained is, as a matter of fact, wholly erroneous. There is also a doubt regarding the correctness of certain notes of Harrington on the habits of the snowy tree cricket, which has a bearing on this subject. Howard quotes Harrington as mentioning the following: "An interesting feature of its concerts is one of which I have not been able to find any mention in books accessible. While the male is energetically shuffling together his wings raised almost vertically, the female may be seen with her head applied to the base of the wings, evidently eager to get the full benefit of every note produced." (*Insect Book*, p. 344.) My studies of the thoracic gland of the snowy cricket show this structure to be similar to that of the striped species, *fasciatus*; consequently, is it not possible that Harrington witnessed the female in the act of drinking from the gland without realizing the entire mission of her attitude? Blatchley gives an interesting account of the male wooing the female in the work before cited. He found them on the heads of the sunflower.

Besides the alluring gland above referred to, this œcanthid has a singular eversible, sacculated structure situated at the dor-

sum of the abdomen, in the fold between the third and fourth tergites. In handling the living male, and raising the tegmina with one's fingers to an angle of forty-five degrees or more, the gland may be detected. It does not protrude except during the first moments of excitement of capture when its folds are thrust out. This would indicate that the structure is a repugnatorial organ, though this is conjectural, there being no odor given off from it. A similar gland occurring in a like situation, on the dorsal aspect of the allied snowy cricket, *C. niveus*, gives to the insect, when likewise excited, a faint odor not unlike some flower.

The Method of Oviposition. — On October first, I examined a large number of the horse-weed and golden-rod a-field, which showed the scars where the crickets had oviposited. The fact was developed that the eggs of this species were always deposited on the sunny south exposure of the main stem of the plants. This is obviously an advantage in furnishing the necessary heat in hatching the eggs, and to the delicate young when they first emerge. In Figure 1 the serial subfigures represent the stems of the blackberry, horse-weed, and golden-rod, all shorn of leaves, to demonstrate the scars or holes, as well as the eggs *in situ*. I witnessed the act of oviposition for the first time on the afternoon of September 12, and thereafter observed it on a number of occasions. In brief the process is as follows: the female coming to a suitable spot on the stem, she prepares it by biting it with her jaws, spending scarcely a minute in doing so. Then, moving her ovipositor under her body at nearly a right angle, she places the tip into this superficial abrasion and immediately proceeds to drill a hole. The drilling is accomplished by rotating the ovipositor while keeping the end, which is provided with a dentate rasp, firmly pressed against the stem. The abdomen, which she turns from side to side, takes an active part in this procedure, acting as upon a pivot, and at times covering about forty degrees in these movements. The ovipositor is soon passed through the tough external covering and finally penetrating deeper and deeper into the pith. In the beginning the course of the hole takes a right angle, but as she proceeds its direction is changed, taking a curved inclination backwards, as

depicted in Figure 1, *d*. When the female has bored into the pith as far as the ovipositor can go, she then discharges the slightly curved egg very slowly. Then after withdrawing the organ, she finishes the process by chewing the stem at the point of entrance as she did in the beginning of the operation. The anterior, whitish tipped pole of the egg usually lies within a millimeter of the opening. This is shown in the specimen of golden-rod (Fig. 1, *d*) laid open for inspection. Some of the eggs here show the whitish micropilar extremity quite clearly. I did not see the female use the same hole for the deposition of more than one egg.

One night at 7.30, under artificial light, I observed a female boring a hole, but when she arrived at the stage where she was about to oviposit, she suddenly pulled out her ovipositor without having accomplished her purpose. It was then disclosed that the egg had stuck in its passage, for the next moment she brought the ovipositor forward underneath her abdomen and, spreading the blades apart, she extracted the egg with her mouth and rapidly ate it. This latter act does not seem to be unusual among the orthoptera under like conditions, as I have witnessed it in several widely different species. She then went over her ovipositor carefully cleaning it with her mouth. Commencing at the tip, she spent several minutes passing from the point along its entire length, giving great attention to the preparation of the base and genitalia. This latter performance seemed to have been done with a view to forestall further accidents, for almost immediately afterwards she started to again oviposit, and this time, as well as thereafter, had no difficulty in placing her eggs successfully.

THE EMBRYO OF THE ANGIOSPERMS.

HAROLD L. LYON.

The angiosperms are the dominant plants of present floras, and were the first to be thoroughly studied by botanists. The seed habit, providing a definite period for embryonic development, and the large embryos, often obtaining as a result, made the embryology of the angiosperms especially easy and attractive. Simple lenses and primitive technique served for the study of these embryos, and a knowledge of them was well advanced before better instruments and better methods were employed to elucidate the embryogeny of lower forms.

The angiospermous embryo was early hit upon as furnishing fundamental data for systematic classification. This quickly brought such embryos into prominence in botanical literature, and controversies immediately arose as to the morphological values and homologies of the embryonic members. While a creed, serviceable and satisfactory to the systematists, was soon evolved, the chief questions in morphology have continued to the present day quite unanswered. The aspect of the problem has changed from time to time with increasing knowledge and if we would now attempt a solution we must strive to answer the three following questions.

Are the angiosperms monophyletic?

Are cotyledons true leaves?

To what structure, if any, in the monocotylous embryo are the cotyledons of a dicotylous embryo equivalent?

An answer to the last question is, of course, the one most generally desired; but to discuss this question one must take some position as to the phylogeny of the classes of angiosperms and to the morphological value of cotyledons.

Are the Angiosperms Monophyletic?

It had been so generally conceded that the angiosperms have a common ancestry that in a former paper the writer (: 02) dis-

missed this question with the following brief statement, "That the Monocotyledons and Dicotyledons have a common ancestry there is no reason to doubt. One would hardly suppose that the similar complicated cytological phenomena of embryo-sac development and endosperm formation were simply parallelisms in two groups of different phylogenetic origin." Later, however, Balfour (:01) in discussing the phylogeny of the angiosperms, said, "Were I to maintain an opinion it would be that the two classes have arisen on separate lines of descent. The embryo characters as well as those of the epicotyl can, I think, be shown to be fundamentally different and to afford no basis for an assumed phyletic connection."

Since Balfour, Coulter and Chamberlain (:03) have written on the same subject as follows: "The first phase of the problem has to do with the common or independent origin of the Monocotyledons and Dicotyledons. It has been assumed generally that the two groups are monophyletic. The chief argument, and in fact the only morphological one for the monophyletic theory, lies in the great uniformity of the peculiar development of both male and female gametophytes. It is argued that the independent origin of such exact details of development and structure is inconceivable, and this argument has been reënforced recently by the discovery in both groups of the peculiar phenomenon called 'double fertilization.' The argument is certainly a very strong one, and yet there are rebutting propositions. Even such similarity in structure may be the natural outcome of the changes that resulted in the evolution of seeds, and these are now generally believed to have appeared in independent lines. Again, the fundamental differences in the development of the embryos of the two groups are hard to reconcile upon the theory of monophyletic origin. Add to this the fundamental differences in the structure of the stem and in the character of its vascular bundles, and the derivation of one group from the other seems more inconceivable than the derivation of the Dicotyledons from the Gymnosperms. Still another argument against the monophyletic theory is furnished by the historical testimony. The Proangiosperms of the Lower Cretaceous, so far as known, appeared associated with undoubted Mono-

cotyledons, and merged gradually into recognizable Dicotyledons. The emerging of Dicotyledons from this vague group either indicates that Monocotyledons and Dicotyledons originated independently, or that the Proangiosperms were transition forms between Monocotyledons and Dicotyledons. This latter alternative is in turn inconceivable, especially since the most primitive Dicotyledons are recognized to be even more primitive than any of the Monocotyledons. . . . . In our judgment the evidence is strongly in favor of the independent origin of the two groups, which have attained practically the same advancement in the essential morphological structures, but are very diverse in their more superficial features. Their great distinctness now indicates either that they were always distinct or that they originated from forms that were really Proangiosperms and neither Monocotyledons nor Dicotyledons."

Few morphologists will agree with the statement that the only morphological argument in favor of the monophyletic theory is to be derived from the similarity in embryo and endosperm development. There is in both classes a remarkable conformity to one common plan in all phases of their organogeny; not only in the embryo-sac, but in the development of floral structures, andrœcia, gynœcia, ovules, seeds and fruits. While many similarities in plant structures have undoubtedly resulted through parallel development, is it not carrying the idea to an unwarranted extreme when it is attempted to explain all the exact details of development, which obtain alike in both classes of Angiosperms, as simply parallelisms, especially since no tangible evidence is brought forward to justify it?

If the fundamental differences in embryogeny are to be delineated by the exceptionally perfected embryos of Alisma and Bursa, as is so generally stated, they might be considered hard to reconcile. If on the other hand they are to be determined by a comprehensive comparison of the various types of embryos to be found in the two classes, the real difficulty is not, how to reconcile these differences, but how to locate them. An examination of recent embryological work [1] will show that no *funda-*

[1] Sterckx ('99), Lyon (:01), Cook (:02), Schmid (:02), Sargant (:02, :03, :04), Schaffner (:04), York (:04).

mental differences can be distinguished. Coulter and Chamberlain themselves in a previous chapter of the same work, write, "The distinction between Monocotyledons and Dicotyledons is not always clear in the embryo."

Should fundamental differences in the structure of the stem and its vascular bundles be pointed out, this "*rebutting proposition*" might prove a serious one. It is certain, however, that such an opinion can carry little weight when opposed to the conclusions of careful investigators supported by their researches. And almost without an exception, students[1] who have actually worked on the stem anatomy of the angiosperms with a view to determining their phylogeny, concur in the opinion that here also the evidence is for and not against a monophyletic origin. There is a characteristic type of stem and bundle structure prevalent in each class it is true, but in certain plants of both they so closely approximate a common type that no hard and fast line can be drawn between the classes on this basis. That both types have been evolved within the angiosperms from one fundamental pattern is amply demonstrated by existing plants as the above mentioned students have shown. Coulter and Chamberlain (:03) would place the Nymphæaceæ among the dicotyledons because of their embryo-characters; but no one has ever been able to show that the stem structure of the Nymphæaceæ is other than essentially that characteristic of monocotyledons. In placing the Nymphæaceæ as they do, they themselves admit that there are no differences in stem structure between the plants of the two classes which are fundamental.

As to the historical testimony which is to be derived from palæobotany, Seward (:03) has shown that, in the extent of our present knowledge, it is to be considered of questionable value.

While giving due consideration to these adverse opinions; admitting that an independent origin of the monocotyledons and dicotyledons is not inconceivable, and that all their common morphological, structural and cytological peculiarities might be simply parallelisms; still we are justified in accepting the strongly fortified conclusion, borne out by all obtainable evi-

[1] Queva ('99), Jeffrey (:00, :03), Worsdell (:02), Sargant (:03).

dence, that the angiosperms are monophyletic; that their most recent common ancestors were Angiosperms.

Are Cotyledons true Leaves?

The oldest and at all times the favorite interpretation of cotyledons is that they are arrested or metamorphosed foliage leaves. The antiquity of this view as well as the basis on which it was founded is well set forth in the following quotation from Sachs' *History of Botany*:[1] "We see that Cesalpino uses the same word 'folium' without distinction for calyx, corolla and ordinary leaves; just as he and Malpighi a hundred years later unhesitatingly regarded the cotyledons as metamorphosed leaves. In fact the envelopes of the flower and the cotyledons approach so nearly to the character of leaves that every unprejudiced eye must instinctively perceive the resemblance."

From time to time various authors, while accepting the foliar theory of cotyledons in its general application, have concluded that the analogous structures in certain plants are not true cotyledons but organs of a different morphological value. The scutellum of the grasses, which is now commonly considered a cotyledon, has been variously interpreted.[2] Richard ('11) distinguished as 'Embryons macropodes' the embryos of the grasses, Nelumbo, Ruppia, Hydrocharis and Zostera. The scutellum of the grass embryo and the cotyledonary lobes of the embryo of Nelumbo he considered homologous to the massive, macropodous portions (l'hypoblaste) of the embryos of Ruppia, Zostera and Hydrocharis. This hypoblast he interpreted as a lateral outgrowth or expansion of the radicle. Schaffner (:04) compares the embryos of the Nymphæaceæ with those of Ruppia, Zostera and Halophila. He reiterates Richards conclusions concerning the homology of the cotyledonary lobes with the macropodous body which he terms a hypocotyledonary expansion.

Nageli ('78), however, early ventured the opinion that "Der Embryo der Gefässkryptogamen und der Phanerogamen ist kein Caulom sondern ein Thallom, wie das Moossporangium, aus dem

[1] English translation 1890, p. 48.

[2] *Vide* Bruns ('92) and Kennedy (:00).

er phylogenetisch hervorgegangen ist; die Samenlappen sind keine Phyllome, sondern Thallomlappen. An dem Embryo tritt als neue Bildung der Stengel auf."

In a lecture delivered at the Minnesota Seaside Station in June, 1901, and since published in the Year Book of the station, the writer suggested that cotyledons are not arrested leaves but are primarily haustorial organs, originating phylogenetically as the nursing-foot in the Bryophyta and persisting throughout the higher plants.

Balfour, in his presidential address to the Botanical section of the British Association, September meeting, 1901, said, "We ought, I think, to look upon the embryo of the angiosperms as a protocorm of embryonic tissue adapted to a seed life. Under the influence of its heterotropic nutrition and seed environment it may develop organs not represented in the adult plant, as we see in, for instance, the embryonal intra-ovular and extra-ovular haustoria it often possesses. There is no reason to assume that there must be homologies between the protocorm and the adult outside an axial part with its polarity. There may be homologous organs. But neither in ontogeny nor in phylogeny is there sufficient evidence to show that the parts of the embryo are a reduction of those of the adult. . . . . I cannot pursue the subject here nor discuss the view of the cotyledons as either ancestral leaf-forms or arrested epicotylar leaves. The analogies with existing Pteridophytes that are cited are not pertinent, for there is no evidence that angiosperms have that ancestry, or indeed that their phylogeny was through forms with free embryos. Nor is the fact of resemblance between cotyledons and epicotylar leaves and the existence of transitions between them convincing. That the cotyledons, primarily suctorial organs, should change their function and become leaf-like under the new conditions after germination is no more peculiar than that the hypocotyl should take the form of an epicotylar internode from which it is intrinsically different as the frequent development upon it of hypocotylar buds throughout its extent shows."

While each of the above authors expresses a distinct interpretation quite at variance with those offered by the others, still all declare alike on our present point of discussion, that cotyledons are not morphologically foliage-leaves.

Ramaley (:02), who for the past ten years has been working on the comparative anatomy of dicotyledonous seedlings, expresses his opinion on this subject in the following statement: "I think also that the theory of the above named writer [Preston, :02] to account for the lobing of cotyledons is of no great value. He suggests that the lobing of the foliage leaf is 'thrown back' upon the cotyledon. This assumes firstly that 'throwing back' can actually occur, while as a matter of fact it yet remains to be proven; and secondly, that the cotyledons are homologous with leaves, something which also remains unproven. The suggestion[1] concerning the morphology of the cotyledon made at the recent Chicago meeting of botanists of the central states seems more reasonable than the one which would consider the cotyledons as really a leaf."

Many other writers have expressed dissatisfaction with the foliar theory without taking a decided stand against it. Klebs ('83) in his excellent treatise on germination pronounces the subject an enigma, while Lubbock ('92), who has undoubtedly made more extensive observations upon seedlings than any other one man, writes: "No one who has ever looked at young plants can have failed to be struck by the contrast they afford to the older specimens belonging to the same species. This arises partly from differences in the leaves, partly from the contrast which the cotyledons, or seed-leaves, afford, not only to the final leaves, but even to those by which they are immediately followed. This contrast between the cotyledons and true leaves is so great that one might almost be pardoned for asking whether they can be brought in correlation. So far, indeed, are the cotyledons from agreeing with the forms of the leaves, that the difficulty is to find any which have been clearly influenced by them. One species of Ipomœa (I. Pes-capræ) has both cotyledons and leaves, as the name denotes, somewhat like the foot of a goat: but the leaves vary considerably, and it is probable that the resemblance may be accidental. A clear case is, however, afforded by the Onagrarieæ, where in Œnothera and some allied genera the form of the mature cotyledons is

[1] Lyon (:02).

evidently related to the leaves. Even here, however, the resemblance is confined to a basal portion of the cotyledon which makes its appearance subsequent to germination, and no trace of it is shown in the cotyledons themselves when they first appear."

We can readily see from Lubbock's work that a morphological leaf-value has been ascribed to cotyledons solely on their resemblance to foliage leaves, a resemblance which is acquired after germination when the cotyledons are functioning as photosynthetic areas. Then they are only in general leaf-like, for if any cotyledons be compared with the foliage leaves of the same plant they are found to differ from these, usually to a marked degree in form, texture and venation. The resemblance is never more than such as might be wholly induced by the assumption of the vegetative function, for the cotyledons become functionally similar structures in the same environment as the leaves. Natural forces seem to call forth a remarkably constant type of foliar organ in all those plants where any extent of tissue is specialized for this purpose no matter what the morphological value of the tissue may be. The gametophytes of some mosses develop leaves which are quite similar to the simpler leaves produced by the sporophytes of many pteridophytes and phanerogams. Phyllodes and Phylloclades are well known cases where the assumption of the function has, in many instances, been followed by the assumption of the form of leaves.

Ramaley has undertaken a study of the comparative anatomy of cotyledons and leaves. In his paper (:03) on the cotyledons and leaves of the Papilionaceæ, he writes: "In the plants examined, all of which have cotyledons which function for a time as leaves, the anatomical structure is strikingly different in cotyledons and leaves. . . . . The stalk of the cotyledon when present has a structure different from that of the leaf-stalk." Again (:04) he writes: "In the Ranunculaceæ and Cruciferæ studied there is not as great a difference in structure between cotyledons and leaves as was seen in the Papilionaceæ. . . . . The stalks of the cotyledon and leaf are quite different in anatomical structure. . . . . In these families as in the Papilionaceæ there seems to be no relation in external form between the cotyledon and leaf."

The ontogenetic origin of the cotyledons would seem to deny the foliar theory since they do not arise as exogenous lateral outgrowths upon the growing point of the stem as do all later foliar structures. Their appearance always precedes the differentiation of the stem-apex.

Thus it appears that the foliar theory is supported only by the fact that in some plants the cotyledons are borne on a stem and are green, and may acquire a form resembling a leaf. It seems certain that any "unprejudiced" observer must at once admit that these are but superficial analogies; quite insufficient evidence to warrant the conclusions so universally based upon them.

To what Structure, if any, in the Monocotylous Embryo are the Cotyledons of a Dicotylous Embryo Equivalent?

Early embryologists considered the cotyledons of all angiosperms (with the exceptions already noted) to be structures of the same category, morphologically as well as physiologically, and their conclusions have been accepted by botanists in general.

Balfour (:01), however, states that, "This terminal cotyledon in the Monocotyledons is not a leaf nor the homologue of the lateral cotyledons in the Dicotyledons."

In this opinion he is again supported by Coulter and Chamberlain (:03): "The current opinion regards it [the cotyledon] as a modified foliage leaf, and this is borne out in the majority of Dicotyledons by the assumption of the foliage function. The terminal cotyledon of Monocotyledons, however, seems to belong to a different category, and to hold no relation to a foliage leaf or to a foliar member of any description." To discover evidence which will in general prove the homology of the cotyledons, one has but to consult the recent works of Sterckx ('99), Lyon (:01), Cook (:02), Schmid (:02), Sargant (:02, :03, :04), Schaffner (:04) and York (:04). Just as the observations of the above mentioned investigators dispel all idea of such fundamental differences in the embryos as would indicate two types of different phylogenetic origin, so also do they show clearly that the coty-

ledons of the angiosperms are morphologically of one category. In 1809 Poiteau published the theory that the epiblast of certain grasses represents a vestigial cotyledon thus indicating a dicotyledonous origin for these plants. This hypothesis has won many adherents and but recently Van Tieghem ('98) has, on the strength of it, placed the Grasses with the Nymphaeaceae under a third class of angiosperms which he calls Liorhiza dicotyledons. Van Tieghem's classification has been adequately dealt with by Balfour (:01, :02) and needs no further attention from us at this time. Poiteau's idea of the reduction of one cotyledon was employed by Henslow ('93) to explain the origin of the monocotylous condition throughout the Monocotyledons.

Agardh ('29–'32) also accepted Poiteau's interpretation of the grass-embryo but considered the Gramineæ the only true monocotyledons. The Naiadeæ, Palmæ, Aroideæ, Lilieæ and Scitamineæ, and probably other families of monocotyledons, he classed as syncotyledones, considering the terminal structure of their embryos to represent two cotyledons which had become fused into a single member.

In a previous paper, the writer (:02) also concluded that the cotyledon of a monocotyledon was equivalent to both of the cotyledons of a dicotyledon, but that the monocotylous condition was the more primitive and that from this the dicotylous condition had arisen through a bifurcation of the originally single cotyledon. The morphological value ascribed to the cotyledon led primarily to this conclusion which was further strengthened by embryological studies in the Nymphæaceæ.

In a series of admirable papers, Miss Sargant (:02, :03, :04) has brought together much evidence, of which her own research work has furnished a very important part, showing that the cotyledon of a monocotylous embryo is equivalent to both of the cotyledons of the dicotylous embryo. Add to this the evidence from the Nymphæaceæ embodied in the recent works of Lyon (:01), Cook (:02), Schaffner (:04), and York (:04) and the conclusion would seem a necessity. In considering the phylogeny of the angiosperms, however, Miss Sargant has accepted the view suggested by Agardh, that the monocotylous condition has been derived from the dicotylous condition through the fusion of

two cotyledons into a single member. Thus while the relative value of the cotyledons in the two classes needs no further discussion at this time, we have yet to choose between the hypothesis elaborated by Miss Sargant and the one suggested by the writer.

It is obvious that the anatomical and morphological evidence collected by Miss Sargant can as readily be interpreted in support of the writer's hypothesis as the one brought forward by herself. It can quite as well be interpreted as showing a transition from the monocotylous to the dicotylous condition by a bifurcation of the cotyledon, as demonstrating a reduction from the dicotylous to the monocotylous condition through a fusion of two cotyledons. It can be read forward as well as backward. Progression in evolution is quite as plausible as retrogression, yet Miss Sargant hopes to convince her readers with the following unique argument: "To conceive of steps by which two separate cotyledons should gradually unite is easier than to imagine a single cotyledon splitting into two similar members as suggested by Mr. H. L. Lyon."

While Miss Sargant is able to cite some thirty dicotyledonous seedlings as having their cotyledons partially or completely united into a single member, one might easily mention a hundred dicotyledonous seedlings having their cotyledons deeply emarginate, bifid or even bipartite. Then cotyledons deeply three-lobed, four-lobed, and five-lobed are not unknown. In various species of Acer, seedlings with three and four distinct cotyledons are of frequent occurrence. *Pittosporum crassifolium* produces three or four cotyledons quite as often as two, while *Nuytsia floribunda* habitually produces embryos with three or four cotyledons. Would the writer propound an inconceivable hypothesis were he to suggest that in these dicotyledons the variously lobed and polycotyledonous conditions had arisen through a splitting of cotyledons; or must he adopt that "easier" line of reasoning and maintain that the polycotyledonous condition is the more primitive, and that the dicotyledonous condition has been arrived at through a reduction by the gradual union of the many members into two? All morphologists will affirm that this lobing of the cotyledons has resulted through adaptation to the various

conditions imposed by the seeds. Might not these same causes, whose effect on two cotyledons is so often apparent, have primarily induced the division of a single cotyledon into two? In considering divided cotyledons, Lubbock ('92), concludes that the bifurcation of the cotyledons in such plants as Eschscholtzia and Schizopetalon are adaptations whereby the cotyledons are better able to free themselves from the seed. If for this purpose four cotyledons are superior to two, in what far greater proportion are two cotyledons superior to one?

Although its evidence can never be taken as absolute, still we are justified in placing some value on recapitulatory development. If the monocotylous condition arose through the union of two cotyledons we might reasonably expect to find, in our transition-types, that two distinct cotyledon-primordia would first appear, and conjoint development occur later. Such a sequence we actually find in the development of gamophyllous perianths. But in all the anomalous forms cited by Miss Sargant, of which the embryogeny has been studied, a single primordium first appears which, if the cotyledon is to become lobed at all, later bifurcates.

In her first paper on this subject, Miss Sargant (:02) attributed the reduction of the cotyledons to their specialization as a sucking organ. Of the monocotyledons, she writes, "I have regarded them for some time as specialized forms of an ancestor with two seed-leaves. The complete union of the cotyledons may very possibly be due to their common specilization as a sucking organ. It is true that all cotyledons begin life by absorbing nourishment from a food-body within the seed, but in dicotyledonous seedlings they commonly lay aside that function at an early period, even though they may never become assimilating organs. Among Monocotyledons on the contrary, the apex of the cotyledon often remains within the endosperm throughout the existence of both, a period which covers years in palms and some other plants. Such a habit as this would naturally lead in course of time to the fusion of the cotyledons within the seed." This hypothesis would seem to maintain that the specialization in seeds has been from the exalbuminous towards the albuminous condition. This supposition however meets

with immediate denial from our knowledge of the phylogeny of seeds.

In her later papers, Miss Sargant (: 03, : 04) fails to reiterate the above hypothesis of the reduction factor but says: "These considerations have led me to look upon the Monocotyledon as an organism adapted primarily to a geophilous habit," and "Suppose a race of primitive Angiosperms to be specialized as geophytes. Their originally distinct cotyledons become more and more closely united in order to economize material. In the end a single cotyledonary member is formed by their complete fusion. A monocotyledonous race might easily be derived in this way from one with two cotyledons." While it is possibly true that the development of cotyledonary tubes has resulted in some dicotyledons through adaptation to a geophilous habit; just how this habit might have caused a fusion and subsequent reduction of the blades of the cotyledons, Miss Sargant does not make clear in any of her papers; and how the habit should finally force the cotyledon into the subterranean position characteristic of monocotyledons receives no explanation at all. Furthermore, her hypothesis would seem to require that the primitive angiosperms were not geophytes. It is now commonly held that the angiosperms are the progeny of pteridophytic ancestors, and it might be well to consider that the geophilous habit is quite prevalent among the Pteridophyta.

Finally, the entire structure of Miss Sargant's theory is built upon the assumption that cotyledons are morphologically foliage-leaves. But we have already found that this assumption is disproved by our knowledge of the form, structure, and development of cotyledons. To make her theory seem tenable, Miss Sargant must first make plausible this assumed premise on which the validity of her hypothesis so largely depends.

Recapitulation.

The great value ascribed to the embryo in the systematic classification of the Angiosperms early brought such embryos into prominence in botanical literature. Thus we find that angiospermic embryology embodied an extensive knowledge

before any careful work had been done on the cryptogams. As a result an interpretation of the angiospermic embryo was evolved wholly from evidence obtained from angiosperms and without reference to any evidence which cryptogamic embryos might furnish. This interpretation in the hands of the systematists soon became a fixed creed which has come down to the present day as built upon facts too well established to be questioned. Some morphologists have, it is true, attacked this creed, but have failed to lessen in the slightest degree its general acceptance.

Because the cotyledons of certain plants assumed the function and approximated the form of leaves, a morphological leaf-value was, from the first, ascribed to them. This hypothesis, framed on simple analogy, is the self-evident fact which constitutes the basis for all later acceptable embryological considerations. If cotyledons are morphologically foliage leaves, that the most primitive angiosperms must be those of which the cotyledons most nearly approach foliage leaves, is a conclusion which naturally followed. And hence the creed recognized the dicotyledons as the most primitive and considered the monocotyledons a race derived from them. Some theorists would derive the monocotylous condition from the dicotylous, by the abortion of one cotyledon, and others, through the fusion of the two cotyledons into a single member.

Following, and followed by others, the writer has concluded that cotyledons are not metamorphosed foliage leaves. The writer has further suggested that they are primarily haustorial organs originating phylogenetically as the nursing-foot of the Bryophytes and persisting throughout the higher plants; that the monocotylous condition is the more primitive and that the dicotylous condition has arisen through a bifurcation of an originally single cotyledon.

There are, it is true, certain dicotyledons which show a tendency to reduce one cotyledon and others in which a partial or complete fusion of the cotyledon petioles undoubtedly takes place, yet there is no evidence to justify the sweeping application of either process in explaining the origin of the monocotylous condition.

The embryos of the so-called anomalous dicotyledons can as readily be interpreted as demonstrating the bifurcation of one cotyledon as proving the fusion of two, and if we take into account the course of events in their ontogeny they support the former hypothesis in preference to the latter.

While, as mentioned above, some few dicotyledons show a tendency to reduce the cotyledons there is an opposite tendency far more prevalent among dicotyledons to produce lobed, bifid and bipartite cotyledons; undeniably a process of splitting.

Finally if the foliar-theory of cotyledons can be established the writer's entire hypothesis must fall. If the adverse hypotheses are to be proven, the foliar-theory must first be established.

The Phylogeny of the Cotyledon.

In a paper now in preparation, the writer will endeavor to demonstrate the validity of his hypothesis concerning the phylogeny of the cotyledon. A previous paper (:02) on this subject only served to indicate in an indefinite way the scope of the theory. Since that time continued investigations in the field, laboratory and library have yielded evidence which bears out to a remarkable degree the fundamental idea, at the same time furnishing the necessary details for a more exact formulation of the hypothesis. The following outline illustrates the application of this hypothesis to plant embryology.

Cryptogamic embryos. — The first regional differentiation of the body-tissue of the sporophyte was into the spore-containing capsule and the bulbous nursing-foot; the function of the former being the bearing and protection of the spores, that of the latter the absorption of nourishment and the furnishing of mechanical support. Since these two regions form the bases for all later elaboration of the sporophyte we may conveniently assign to them the distinctive names of *sporophore* and *haustrum*. As the haustrum and sporophore are not always distinguishable from the first in the embryo we will find the term *protocorm*[1] quite ser-

[1] This admirable term was first used by Treub ('88) to designate the "embryonic tubercules" of various lycopods. The writer simply extends the use of the term without seriously altering its original meaning.

viceable as designating the whole embryo before this primary differentiation is complete, and the term *metacorm* for the plant body after the differentiation of its permanent members. All of the protocorm or only a portion of its tissue may be employed in the formation of the metacormal primordia.

In the Bryophyta the haustrum remains embedded in the tissue of the gametophyte throughout its own existence, but in the Pteridophyta it acquires the habit of anchoring the sporophyte in the soil after the tissue of the gametophyte is exhausted. This seems to have at first resulted in the production of a large, bulbous haustrum (Phylloglossum, *Lycopodium cernuum*) but later some haustral tissue became modified into a distinctive earth-boring organ, the root, a structure much better adapted for penetrating and drawing water from the soil. In *Lycopodium cernuum* the bulbous haustrum may give rise to roots, which in turn may be converted back into bulbous haustra. While some lycopods produce large, bulbous, geophilous haustra, among the pteridophytes, as a rule, a bulbous haustrum is employed only in connection with the gametophyte, the haustral tissue which penetrates the soil being differentiated into a root. Thus the primary bulbous haustrum of the bryophytes becomes differentiated in the pteridophytes into two distinct haustral organs; the nursing-foot or cotyledon — the haustrum of the protocorm, and the root — the haustrum of the metacorm.

The capsular sporophore of the Bryophyta gives place in the Pteridophyta to an axis bearing sporophylls. Because of their position, the photosynthetic work falls upon the sporophylls, and this very soon leads to a division of labor with a consequent sterilization of some sporophylls as foliage leaves or euphylls. While phylogenetically the sporophore precedes the haustrum, the requirements of the former during its development upon the latter, seems to have stimulated an ontogenetic acceleration of the haustrum and a corresponding retardation of the sporophore, so that in ontogeny a functional haustrum precedes the sporophore. Thus in the embryogeny of Anthoceros and Sphagnum we find that of the massive protocorms first developed the greater portion is haustral tissue on which the sporophore stands as a papilla. Among the pteridophytes the ontogenetic acceler-

ation of the haustrum is always apparent so that their protocorms are essentially haustral structures from which the sporophore sooner or later develops as an outgrowth. In Phylloglossum the ontogenetic acceleration of the haustrum is most pronounced, a large bulbous protocorm resulting, from which the sporophore is differentiated at a quite late period (Fig. 2). As the protocorm of this plant becomes geophilous, it develops leaf-like lobes of tissue which carry on photosynthetic work. Bower ('94) terms these protocormal leaves, *protophylls*, to distinguish them from the leaves of the metacorm, the euphylls. With the specialization of the root as the earth-boring haustrum and the euphylls as the photosynthetic areas, the geophilous protocorm with its protophylls disappears from the ontogeny of the higher pteridophytes as we have already found. Perhaps, however, the first leaf of some of these should be interpreted as a protophyll rather than a euphyll.

In the embryogeny of Lycopodium and Selaginella an outgrowth from the protocorm serves to carry the embryo down into the tissue of the gametophyte. This protocormal organ, the suspensor, is limited to the lycopods among the pteridophytes but is of general occurrence in the embryogeny of the angiosperms.

The positional relation which the metacorm bears to the protocorm is remarkably different in different cryptogamic embryos. In the Bryophyta the axis of the metacorm is coincident with the axis of the protocorm, the haustrum of the latter developing into the haustrum of the mature plant. With the advent of the root as the haustral organ of the metacorm, the position in which it is differentiated in relation to the sporophore determines the primary axis of the metacorm. In some embryos the root is differentiated out of the body of the protocormal haustrum, while in others it appears as an outgrowth from this structure. In *Botrychium obliquum* and Equisetum, the root appears diametrically opposite the sporophore and hence the metacormal axis transfixes the protocorm, the tissue of the latter becoming a permanent part of the metacorm. In Selaginella, the metacormal axis is differentiated through the tissue of the protocorm, the suspensor being on one side of the axis, and the cotyledon on the

other (Fig. 3). In the leptosporangiate ferns, the sporophore and root appear as adjacent outgrowths from the protocorm thus leaving the haustrum of the latter as a lateral cotyledon on one side of the metacormal axis (Fig. 4).

Angiospermic embryos.— In the embryogeny of an angiosperm, a more or less massive protocorm is developed which may, or may not employ a suspensor. The form of the protocorm varies greatly, depending upon the shape and size of the seed, the extent and vigor of the endosperm, the duration of intraseminal development and the many other peculiar conditions presented by the seed habit. The sporophore arises as an outgrowth from the protocorm and its intraseminal development is, as a rule, quite restricted. The metacormal axis is always differentiated through protocormal tissue. (Figs. 5, 6, and 7.)

In the monocotyledons, the sporophore primordium usually appears as a distinctly lateral outgrowth from the protocorm: but with the establishment of the metacormal axis between the sporophore and root the remaining protocormal tissue stands in a lateral position to this axis and, as a lateral cotyledon on one side of this axis, it functions during germination. As the sporophore primordium of a monocotyledon differentiates into the plumule the adjacent protocormal tissue grows forward around it, often completely enclosing it.

In the dicotyledons, the protocorm early bifurcates and the sporophore primordium arises as an outgrowth between these two cotyledons which closely invest it during intraseminal growth (Fig. 7). In many dicotyledons, a new structure, the hypocotyl, appears in the morphogenesis of the metacorm. The hypocotyl is differentiated between the root and sporophore from tissue which is phylogenetically haustral. During germination it serves to elevate the cotyledons and plumule. The cotyledons upon becoming exposed to the light usually become green and often function for a considerable time as photosynthetic areas. The assumption of the function of foliage leaves leads to the assumption of the form of such leaves, and the cotyledons of some plants approximate to a remarkable degree the form of the later euphylls.

Gymnospermic embryos.— That the gymnosperms in the ear-

lier stages of their embryogeny show a great diversity has been known for a long time. That this diversity is but the more or less restricted following of one general plan has been pointed out by Coulter and Chamberlain (: 03[2]). Up to the present time the knowledge of the later stages of their embryogeny has been quite insufficient for determining the morphological values of the embryonic structures. Recent investigation, however, has served to elucidate some of the obscure points, and the interpretation that would now be offered is as follows.

In Ginkgo a large spherical protocorm is developed in the venter of the archegonium. The blastema (metacormal bud) arises as an outgrowth from the deepest seated portion of the protocorm and invades the tissue of the gametophyte by its own growth. The stem and root primordia are both differentiated entirely beyond the bulbous protocorm, the axis of the three members being along one straight line (Fig. 8). Upon germination, the protocorm is the first member to be forced out of the seed and it is followed first by the root and then by the stem. Thus the protocormal haustrum, because of its position, cannot be employed by the metacorm during germination as a functioning cotyledon. If any structure is to remain in contact with the tissue of the gametophyte, it devolves upon the appendages of the stem, and in Ginkgo we find the first two or three euphylls functioning as absorbing organs or pseudocotyledons.

Ginkgo undoubtedly shows, in its embryogeny, the most primitive condition of any of the gymnosperms, for it certainly shows the least specialization. In Cycas (Fig. 9) a less perfect protocorm is developed and in Zamia (Fig. 10) a further reduction of its bulk obtains. In fact it would seem that because of the positional relation of the blastema to the protocorm the latter cannot be made use of by the germinating embryo, and its disuse leads to an increasing limitation of the structure in gymnospermous embryogeny.

In the cycads, protocormal tissue directly behind the blastema, by rapid growth, carries the metacormal bud down into the tissue of the gametophyte (Figs. 9 and 10). This structure, the suspensor, becomes an organ of importance and is retained by all of the Coniferales. Their protocorms, however, consist of little

more than a suspensor at the tip of which the metacormal primordia are differentiated (Fig. 11).

The suspensor of a gymnosperm embryo is clearly not homologous to that of a lycopod or angiosperm embryo. In the gymnosperms, the suspensor is developed between the body of the protocorm and the blastema and by its elongation serves to separate these two structures. In the lycopods and angiosperms, it is an outgrowth from the protocorm and has one free end. In these embryos the metacormal axis is differentiated through the body of the protocorm.

Polyembryony sometimes occurs in both gymnosperms and angiosperms through the production of two or more blastemata by one protocorm.

UNIVERSITY OF MINNESOTA.

BIBLIOGRAPHY.

AGARDH, C. A.
'29–'32. Lärobok i Botanik. Part 1.

BALFOUR, I. B.
:01. The Angiosperms. Address to the botanical section, Brit. Assn. Adv. Sci. Glasgow. Nature, 64, 557–562.

BALFOUR, I. B.
:02. Angiosperms. Reprinted from the new volumes of the Encyclopædia Britannica.

BOWER, F. O.
'94. Studies in the morphology of spore-producing members. Equisetineæ and Lycopodineæ. Roy. Soc. Phil. Trans., 185, 473–572.

BRUNS, ERICH.
'92. Der Grasembryo. Flora, 76, 1–33.

COOK, M. T.
:02. Development of the embryo-sac and embryo of Castalia odorata and Nymphæa advena. Bull. Torr. Bot. Club, 29, 211–220.

COULTER, J. M. and CHAMBERLAIN, C. J.
:03. Morphology of Angiosperms.

COULTER, J. M. and CHAMBERLAIN, C. J.
:03². The embryogeny of Zamia. Bot. Gaz., 35, 184–194.

HENSLOW, G.

'93. A theoretical origin of Endogens from Exogens through self-adaptation to an aquatic habit. Journ. Linn. Soc. Bot., 29, 485–528.

JEFFREY, E. C.

:00. The morphology of the central cylinder in the Angiosperms. Reprint from Trans. of the Canadian Inst.

JEFFREY, E. C.

:03. Comparative anatomy of Angiosperms. In Coulter and Chamberlain's Morphology of Angiosperms, 311–316.

KENNEDY, P. B.

:00. The structure of the caryopsis of Grasses with reference to their morphology and classification. Bull. No. 19, U. S. Dept. of Agrostology.

KLEBS, G.

'83. Beiträge zur Morphologie und Biologie der Keimung. Untersuch. aus dem Bot. Inst. zu Tübingen, 1, 536–614.

LUBBOCK, SIR J.

'92. A contribution to our knowledge of seedlings. Vols. 1 and 2.

LYON, H. L.

:01. Observations on the embryogeny of Nelumbo. Minn. Bot. Studies, 2, 643–655.

LYON, H. L.

:02. The phylogeny of the cotyledon. Postelsia, 55–86.

NAEGELI, C.

'78. Ueber das Scheitelwachsthum der Phanerogamen. Bot. Zeit., 124–126.

POITEAU, A.

:09. Mémoire sur l'Embryon des Graminées, des Cypéracées et du Nelumbo. Paris, Mus. Hist. Nat. Annal., 13, 381–400.

PRESTON, C. E.

:02. Two instructive seedlings. Bot. Gaz., 33, 150–154.

QUEVA, C.

:00. Contributions à l'anatomie des Monocotyledonées. Mem. de l'Université de Lille.

RAMALEY, F.

:02. The trichome structures of Erodium cicutarium. Bot. Gaz., 34, 140–142.

RAMALEY, F.

:03. The cotyledons and leaves of certain Papilionaceæ. The Univ. of Colorado Studies, 1, 239–243.

RAMALEY, F.

:04. Anatomy of cotyledons. Bot. Gaz., 37, 388–389.

RICHARD, L. C.

'11. Analyse botanique des embryons endorhizes ou Monocotylédonés, et particulièrement de celui des Graminées. Paris. Mus. Hist. Nat. Annal., 17, 223–251, 442–487.

SACHS, J.

'90. History of Botany. English translation.

SARGANT, Miss ETHEL.

:02. The origin of the seed-leaf in Monocotyledons. The New Phytologist, 1, 107–113.

SARGANT, Miss ETHEL.

:03. A theory of the origin of Monocotyledons, founded on the structure of their seedlings. Ann. of Bot., 17, 1–92.

SARGANT, Miss ETHEL.

:04. The evolution of Monocotyledons. Bot. Gaz., 37, 325–345.

SCHAFFNER, J. H.

:04. Some morphological peculiarities of the Nymphæaceæ and Helobiæ. Ohio Nat., 4, 83–92.

SCHMID, B.

:02. Beiträge zur Embryo-entwickelung einiger Dicotylen. Bot. Zeit., 207–230.

SEWARD, A. C.

:03. The origin of flowering plants. The New Phytologist, 2, 243–244.

STERCKX, R.

:00. Recherches anatomiques sur l'embryon et les plantules dans la famille des Renonculacées. Archives de L'Institut Botanique de l'Université de Liége, Third memoir, Vol. 2.

TREUB, M.

'88. Etudes sur les Lycopodiacées. Considérations théoriques. Ann. du Jard. Bot de Buitenzorg, 8, 23–34.

VAN TIEGHEM, PH.

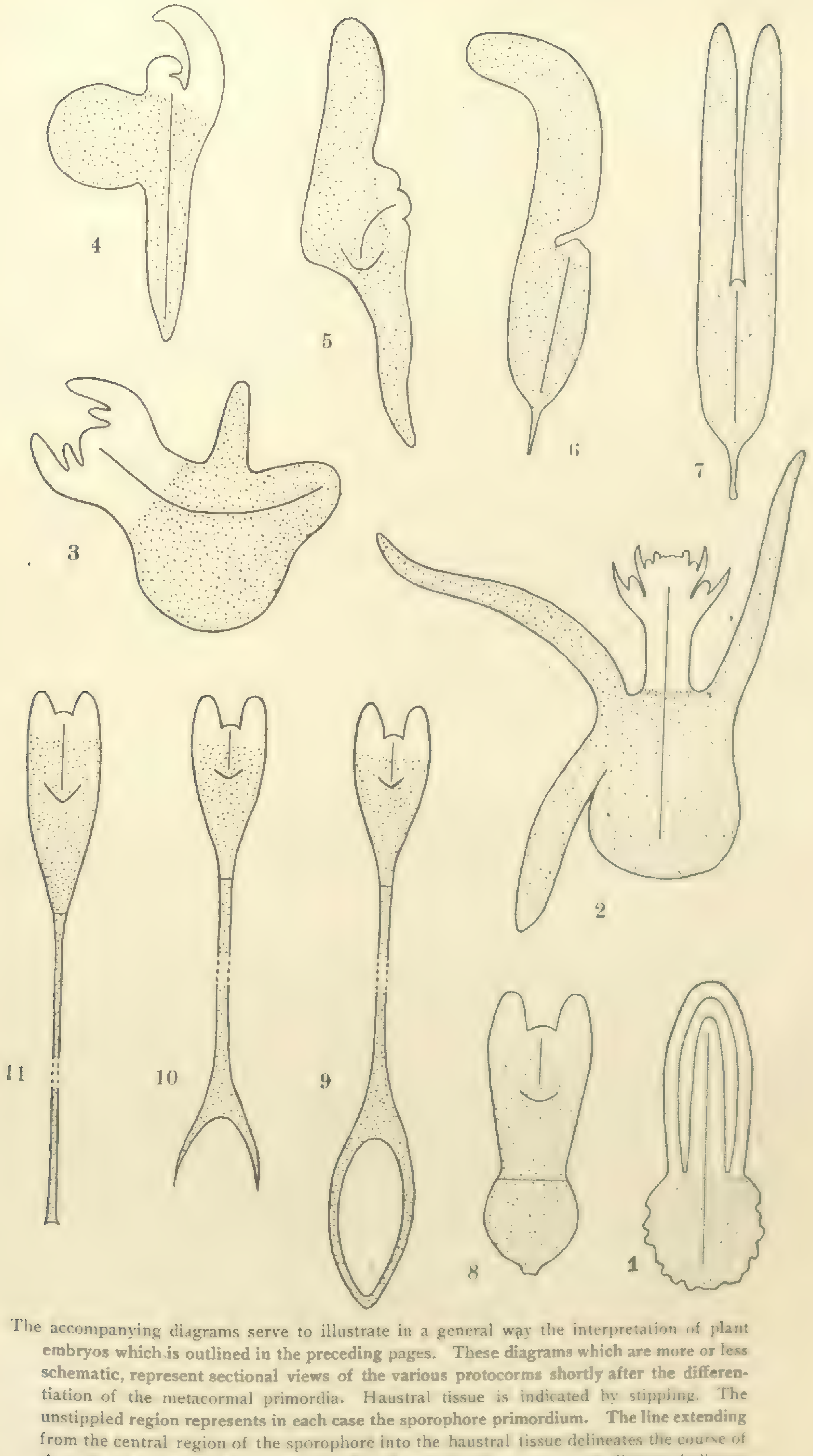
'98. Éléments de Botanique.

WORSDELL, W. C.

:02. The nature of the vascular system of the stem in certain dicotyledonous orders. Ann. of Bot., 16, 599–600.

YORK, H. H.

:04. The Embryo-sac and embryo of Nelumbo. Ohio Nat., 4, 167–176.



The accompanying diagrams serve to illustrate in a general way the interpretation of plant embryos which is outlined in the preceding pages. These diagrams which are more or less schematic, represent sectional views of the various protocorms shortly after the differentiation of the metacormal primordia. Haustral tissue is indicated by stippling. The unstippled region represents in each case the sporophore primordium. The line extending from the central region of the sporophore into the haustral tissue delineates the course of the primary axis of the metacorm. In Fig. 8 to 11, the line across each diagram indicates the juncture of protocormal and metacormal tissue. All of the tissue above this point is originated by the metacormal meristems after their differentiation.

1. Anthoceros. 2. Phylloglossum. 3. Selaginella. 4. Pteris. 5. Zeamais. 6. Alisma. 7. Bursa. 8. Ginkgo. 9. Cycas. 10. Zamia. 11. Pinus.

NOTES ON THE COMMENSALS FOUND IN THE TUBES OF *CHÆTOPTERUS PERGAMENTACEUS.*

H. E. ENDERS.

WHILE I was collecting *Chætopterus pergamentaceus* during the past summer on the shoals about Beaufort,[1] North Carolina, I became interested in the commensals which occur with this annelid, and their number and variety led me to study their habits.

These annelids, which grow in broadly U-shaped parchment tubes, are imbedded in diatomaceous, sandy shoals with from two to five centimeters of their free slender ends (about seven millimeters or less in diameter) protruding above the sand flats at or below low-tide level. These tubes serve as convenient temporary shelters for several species of small animals, and as the permanent abodes of others.

Of ninety-nine tubes collected and opened eleven were found without commensals while the remaining eighty-eight enclosed two annelids of the genus Nereis also one hundred and seventy-six crabs of the species[2] *Polyonyx macrocheles* (formerly *Porcellana macrocheles*), *Pinnixa chætopterana*, *Pinnotheres maculatus*, and one species of "stone crab," Menippe.[3] Polyonyx and Pinnixa are found either singly or together in the same tube, but usually in pairs, male and female, of a single species. Among the number of tubes collected seventy-five enclosed Polyonyx in pairs or singly (total 143); fifteen enclosed Pinnixa; two, Pinnotheres, and one, a "stone crab," Menippe, while two serpulids,

[1] I am indebted to the Hon. Geo. M. Bowers, U. S. Commissioner of Fish and Fisheries, for the privilege of occupying a table in the Fisheries laboratory at Beaufort, N. C., and to Dr. Caswell Grave, the director, for courtesies shown.

[2] I am also indebted to Miss Mary J. Rathbun, of the U. S. National Museum, for the identification of the species of crabs.

[3] The specimen was mislaid or lost at Beaufort, N. C.

encrusted on a female Pinnixa, may be regarded as an accidental enclosure.

The tubes of Chætopterus are not the only abodes of some of the commensals named: Nereis is found among the shells, rocks and sea-weeds; *Pinnotheres maculatus*, in the shells of *Pinna semi-nuda* like the related species, *P. ostreum*, in the oyster; whilst Menippe commonly keeps in hiding in crevices and pits in rocks and shells. So far as I know, *Polyonyx macrocheles* and *Pinnixa chætopterana*, beyond the young stages, are only very *rarely* found free on the shoals, but *Polyonyx ocellata* is found at Beaufort on the body of Limulus, and sometimes in old shells dredged outside the harbor.

The sizes of the crabs range from two millimeters in width to that of the full-grown animal (thirteen to fourteen millimeters wide), and the smallest ones are of such a size that they could readily pass through the orifices of the tubes, and they probably do so for I have frequently collected tubes with two adult crabs and a single small one but rarely with three full-grown individuals.

The position of the crabs in the interior of the tubes I learned by keeping the Chætopterus and crabs in glass U-tubes, to the open ends of which the annelids constructed inverted parchment funnels, which prevented their escape. While the commensals move about with rapidity they remain at one end of the U-tube, usually the one opposite that occupied by the annelid itself, but when the annelid reverses its position they press past it to the opposite end and there remain bathed in the passing current. The annelids, Nereis, moved along the dorsal wall of the tube and did not interfere with Chætopterus which occupied the ventral portion of the tube.

The commensals, which are usually found near the orifices of the U-tube, are advantageously located for securing food, which, if it consists either of vegetable matter or of copepods and various larvæ which pass through the tube in the moderate current of water, and the worms that may seek shelter in the tube, is very abundant.

The commensals are permanently confined within the tubes of Chætopterus where the breeding is comparatively simplified

because of the presence, in nearly every instance, of male and female in the same tube. I also found tubes containing males only (4) or females only; among the latter the eggs on seven females (six Polyonyx and one Pinnotheres) thus taken were in various stages of development, while two other females had, just a short time before capture, liberated their broods. The mature male of Pinnotheres is small enough to pass into and out of the orifices of the tubes, but how or when the eggs of the isolated individuals of Polyonyx are fertilized remains an open question.

The breeding season of the two more common commensals, Polyonyx and Pinnixa, extends through the whole summer. Females with eggs in all stages of development, together with females which had just liberated their broods, were taken in my first collection, June 21st (1904), and even in my last collection, October 25th, every full-grown female taken bore developing eggs, or had very recently liberated her brood as shown by the few imperfect larvæ clinging to the pleopods, or by the position of the abdomen, or "apron," not being closely appressed to the body. At the time of the last collection the breeding season of Pinnixa must have been near its close but that of Polyonyx continued unabated.

The larvæ do not long remain in the tubes after they are hatched but soon find their way out and they may then be taken in the tow in considerable numbers from June till November.

Young crabs, not over two or three millimeters in width, are found in the tubes during the middle and latter parts of the breeding season, but they are frequently overlooked because of their tendency to press between the appendages or the folds of Chætopterus and hide there. In this manner four young crabs, about two millimeters wide, were overlooked when four tubes were opened, and from each the worm together with two full-grown commensals were removed, and only after the worms were submerged in the killing-fluid did the activity of the crabs make their presence known. Once in the tubes it is quite probable that the crabs remain there and are later prevented, through their own growth, from escaping.

The act of moulting was not observed in these commensals but recently moulted individuals of Polyonyx were taken on

three occasions, the "shells" of which, more or less nearly complete, were still in the same tube with the "soft-shelled" crabs.

When a worm in a tube dies the crabs in the same tube die as a result of the failure of food and properly aërated water. Two tubes were taken in which this might have occurred as was shown by the nearly perfect condition of the extremities of the tubes and by the presence of the bodies of three dead crabs lodged in the necks of the tubes, which were only recently filled with sand.

Whether or not commensalism is an advantage to Chætopterus it seems to be a decided benefit to the crabs, Polyonyx and Pinnixa, grown specimens of which are *rarely* found outside the tubes. The advantage to the crabs is very clearly marked by their prolonged breeding season — virtually an example of protected industry.

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December, 1904.

ON THE LARVA AND SPAT OF THE CANADIAN OYSTER.

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Upon opening the Marine Biological Station of Canada for last summer's work the acting director, Professor Ramsay Wright, assigned to me the diagnosis of bivalve-larvæ occurring in the plankton.

The material was collected over the oyster-beds near Curtain Island, off Malpeque, P. E. I. Oyster-larvæ were first recognized on the 25th of July from which time they were present in the plankton collections until the 1st of Sept.

The free-swimming, pelagic larva of the oyster possesses a characteristic color, brownish-red — suggestive of the soil of its native island shores, a shade which enables it to be immediately distinguished from every other bivalve-larva with which it is associated. The shell is asymmetrical and inequivalve, the left valve being larger, more convex, and with a large umbo, the right smaller, flatter and with a moderate umbo. The umbos have a postero-dorsal position and project backwards and upwards, making the shell broader, deeper and squarer behind and tapering but rounded in front. The largest measure .358 × .365 mm. in length and height, but the height and shape vary according to whichever side is turned towards the observer. Larvæ as small as .131 × .138 mm. already possess the characteristic shape and color.

The internal structure of the larval oyster offers some interesting features. We have been accustomed to think of it as vastly different from other bivalve-larvæ, corresponding to the early assumption of a sessile mode of life. This misconception is due to lack of observation of plankton stages, embryologists having jumped from early veliger or phylembryo to late prodissoconch or even early nepionic periods.

When mounted on a slide the larvæ are accustomed to remain

quiescent and from their deep coloration are difficult to examine but sometimes a more transparent one permits certain organs to be traced. When freshly collected and examined in a watch-glass of pure sea-water many of them exhibit the greatest activity, protruding the velum between the antero-ventral margins of the shell, expanding it somewhat like opening an umbrella, and swimming rapidly about by the violent movement of its cilia. While in motion the heavy shell is suspended below the expanded velum. Jarring the watch-glass will cause the animal to instantly withdraw its velum, at the same time snapping the valves of its shell together and dropping towards the bottom. Upon again assuming activity it may protude a long, slim, ciliated foot from the middle of its ventral surface, just behind the velum. The foot at this period is well developed and is a most capable organ by means of which the animal can creep rapidly about and forcibly flop its heavy shell from one side to the other. It can also bend up along the outside of the shell and perform feeling movements over all parts of the body within the shell. Its lower or posterior surface sometimes appears flattened or even grooved lengthwise and at a short distance from the base of attachment to the body there is a heel-like projection which is doubtless the position of the byssus gland. In the proximal part of the foot, *i. e.*, about the center of the animal, are right and left otocysts each containing about a dozen otoconia. A little before and above these, but more superficial, are two lateral, black pigment-spots (eye-spots). Along each side, past the base of attachment of the foot to the body, lies a series of short gill-filaments, extending from the eye-spot backwards and downwards to near the posterior margin of the shell ; in the oldest free-swimming larvæ there are eight, diminishing in size from before backwards, the last ones being mere knobs ; their lower ends are free, but their upper ends spring from one continuous axis of origin, that, behind the foot, joins its mate of the opposite side near the margins of the mantle. The mouth and œsophagus lie in the median plane immediately below and behind the velum to which they are attached and with which they are protruded and withdrawn. In the quiescent animal the gullet lies between velum and foot, in the median sagittal plane as well

as in, or very near, the median transverse plane of the body. Here it passes dorsalwards, between the first gill-filaments, expanding into the stomach with its large lateral liver-sacs. The intestine passes backwards towards the right, and then forwards towards the left, when it again turns backwards and upwards in the left umbo, and finally downwards in the median plane, over the posterior adductor muscle; the greater part of its folds lie in the larger, left valve. In front and above the velum is a transverse adductor muscle, while below the posterior parts of the umbos is a larger, transverse, posterior adductor muscle; retractor fibers converge from the velum to points in the umbos. Right and left mantle-folds line the inner surfaces of the valves.

Examination of eel-grass, rock-weed and other marine plants, of shells, stones, sand and other objects, revealed no young spat. Bundles of brush were tied to submerged rocks, or weighted with stones and sunk at various places. These were carefully examined at intervals but without result. Window-glass was cut into strips 2 × 6 in. and stood on end in crocks, about a dozen in each held apart by wire racks, the crocks being then set out below low-water level on oyster beds and made secure by building stones around them. Daily examination of the glass was made until, on the 16th Aug., I found my first young oyster-spat. It measured 1.030 × .876 mm. in length and depth and exhibited the characteristic coloration of the pelagic larva. In the centre of its dorsal surface could be distinctly recognized the shell (prodissoconch) of the oldest free-swimming stage (.384 × .369 mm.), securely fixed to the glass by its left valve. The anterior adductor appeared to be moved slightly backwards and upwards from its original position, and the posterior adductor had moved downwards and backwards to a position outside the border of the prodissoconch. Behind it opened the rectum. In front of the adductors and in a direction parallel with them, slanting downwards and backwards, were the axes of two sets of gill-filaments, the deeper (left) of sixteen long filaments with their free ends pointing forwards or forwards and downwards, the upper (right) of about half that number of short filaments that ceased below the posterior adductor muscle. No foot could be recognized. The new spat shell was very thin and

delicate, its prisms easily separating from each other at the margins, while beyond these at places the mantle was sometimes protruded.

Three other spat oysters were procured on glass in the same way, the dates and sizes being: Aug. 19, 1.20 × 1.58 mm.; Aug. 22, .55 × .51 mm.; Aug. 31, .953 × .861 mm.

Search was made daily for spat on natural marine objects and on Sept. 2nd I found the first, on the outer surface of a half-grown oyster shell. It measured 2.3 × 2.4 mm., but instead of having a pink, red, or brown coloration as one would suspect from comparison with the larval or earliest spat stages; or, instead of having a chalky-white appearance as one would judge from comparison with the old oysters; it presented a shining, dark metallic lustre with a few faint radial lines. From this time onwards they were to be found in increasing numbers, and, after being once shown them, the deck hands of the government steamer Ostrea could also find them. Altogether I have observed spat oysters on the shells of the oyster, mussel, clam, quohog, bar-clam, razor-clam, round whelk, and on stones. The objects with which they may be most easily conflicted are the young of *Crepidula fornicata* and colonies of *Ralfsia verrucosa*. At the time of leaving Malpeque, Sept. 20, the largest this year's spat I had seen measured 6 mm. in height, had a dark steel lustre, radiating ridges or lines, and very thin edges; the whole oyster being thin and fitting so solidly against the supporting shell as to require some force with a knife-blade to separate it.

As to the rate of growth my 4th spat oyster on glass was obtained Aug. 31, when it measured .953 × .861 mm. and had about sixteen gill-filaments. On Sept. 7 it measured 1.261 × 1.276 mm. and had about twenty-four gill filaments. A week later it measured 1.661 × 1.753 mm. One might say that it doubled its length and height in two weeks. The smallest oysters were about the size of one's thumb nail. I have put out wire baskets containing numbers of selected, half-grown, living oysters, having black spat attached, to be examined next spring.

MONTREAL, 23 Dec. 1904.

A TABLE TO FACILITATE THE DETERMINATION OF THE MEXICAN SCALE-INSECTS OF THE GENUS ASPIDIOTUS (*SENS. LATISS.*)

T. D. A. COCKERELL.

Of all the Coccidæ injurious to cultivated plants, none are more easily carried to new countries, or more likely to cause trouble, than the species of Aspidiotus, *sens. latiss* (including Chrysomphalus, etc.). Some years ago I prepared for my own use a table of the Mexican forms of this group which were known to be or likely to prove of economic importance, using only characters which could be determined with a hand lens. This table is now presented with the hope that it will be useful to those who have to deal with injurious Coccidæ. The determination from the scale should of course always be confirmed by reference to a detailed account of the insect; but in the majority of cases, at least, the indications of the table will be found correct.

♀ scale elongated . . . . 1.
♀ scale circular or subcircular . . . . 2.

1. ♀ scale linear, $2\frac{1}{2}$ mm. long, $\frac{3}{5}$ mm. broad. (on mango, Frontera) *longissimus* Ckll.
   ♀ scale much broader (on cactus, Frontera) . . *bowreyi* Ckll.
2. ♀ scale minute, less than 1 mm. diam., black or very dark brown or gray . . . . 3.
   ♀ scale ordinary . . . . 4.
3. ♀ scale very convex, exuviæ covered, marked by a ring (on various plants) . . . . *personatus* Comst.
   ♀ scale broad pyriform, first skin exposed (on mesquite, Hermosillo) *prosopidis* Ckll.
4. Scale dark with orange or copper-red exuviæ . . . . 5.
   Scale white or light colored, with darker exuviæ . . . 8.
   Scale blackish or brown, with concolorous or darker exuviæ . 14.
   Scale pale or reddish, with concolorous exuviæ . . . . 19.
5. Exuviæ lateral, at one end of the oval scale; scale black with more or less grayish and whitish concentric strigation; exuviæ deep orange (Cuautla) *dentilobis* Ckll.

Exuviæ central or nearly so . . . . 6.

6. Scale hardly $1\frac{1}{2}$ mm. diam., exuviæ deep reddish (on oak, Amecameca) *ancylus* Putnam.

Scale 2 mm. or over in diameter . . . . 7.

7. Scale slightly raised, the exuviæ coppery, nipple-like (on many plants) *aonidum* (L.)

Scale very flat, exuviæ flat, not nipple-like, large, pale orange (on *Citrus*, etc.) . . . . *scutiformis* Ckll.

8. Exuviæ light yellow or orange . . . . 9.

Exuviæ at least partly brown or black . . . . . . 10.

9. Exuviæ covered (Coahuila) . . . . . *townsendi* Ckll.

Exuviæ exposed (on various plants) . . *hederæ* var. *nerii*, Bouché.

10. First skin black or dark brown, second orange (Salina Cruz.) *tricolor* Ckll.

The exuviæ practically all of one color . . . . . . 11.

11. Small, about 1 mm. diam., exuviæ covered, only conspicuous when rubbed, then shining dark brown or black (on Yucca, Coahuila) *yuccæ* Ckll.

Larger, exuviæ conspicuous without rubbing . . . . 12.

12. Scale convex (on various plants) . . . *acuminatus* Targ.

Scale flat . . . . 13.

13. Scale very dark brown, covered with a chalky-white secretion (on orange, Cuernavaca) . . . . *albopictus* Ckll.

Scale grayish, border more or less whitish (on orange, Linares) *albopictus* var. *leonis* Twns. & Ckll.

14. Exuviæ not conspicuous . . . . 15.

Exuviæ black or very dark. conspicuous . . . . . . 17.

15. Scale light brown (Frontera) . . . *jatrophæ* Twns. & Ckll.

Scale very dark . . . . 16.

16. Scale convex, dark gray (on mimosa, Tampico) . *mimosæ* Comst.

Scale flat, dark brown . . . . *perseæ* Comst.

17. Scale covered by the epidermis of the tree, the shining black exuviæ alone exposed (Orizaba) . . . . *calurus* Ckll.

Scale exposed . . . . 18.

18. Scales 3 mm. diam. (San Luis Potosi) . . *nigropunctatus* Ckll.

Scales 1 to $1\frac{1}{2}$ mm. diam. (on Agave, Toluca) . *agavis*, Twns. & Ckll.

19. Scale rather convex, exuviæ nearly marginal (on grape-vine) *crawii*, Ckll.

Scale flat or flattish, exuviæ not nearly marginal . . . . 20.

20. Scale light brown, exuviæ not marked by a dot and ring (Tehuantepec City) . . . . *reniformis*, Ckll.

Exuviæ marked by a dot and ring . . . . 21.

21. Scale light reddish brown (on various plants) . *dictyospermi*, Morg.

Scale darker (on Citrus, Oaxaca) . . *koebelei*, Twns. & Ckll.

BOULDER, COLORADO.

NOTES AND LITERATURE.

GENERAL BIOLOGY.

Lloyd and Bigelow's Teaching of Biology.[1]— In the joint volume by Professors Lloyd and Bigelow, on the teaching of biology in the secondary schools, the first half of the book, under the sub-title "The Teaching of Botany and Nature Study," comprising some 320 odd pages divided into ten chapters, is by Professor Lloyd. The style, while at times a little abrupt, is convincing and forceful, and much sound common sense is inculcated in this presentation of the subject. The introductory chapter is of the nature of a general exposition of the value of science in education and of the sciences the especial value of biology. The author brings out clearly the importance of biological training, not only from the facts which it teaches, but also, what is more essential, the discipline which it affords. The nature study side of the question is first considered since that subject is first demanded in the schools at the present time. Here we find strong arguments for the necessity of intellectual honesty and against that curse of nature study, sentimentalism. The pitfalls which lie in the way of teachers, in the confusion of teleological and causal interpretations of organic structures, are dwelt upon.

The subject of botany itself is begun in the following chapter and the various aspects of the subject developed in the subsequent ones. The greatest interest perhaps centers in the discussion of the different types of botanical courses. Every modern botanist must agree with the author in his advocacy of a dynamic point of view, rather than the formal morphological one which arises from a lack of a proper consideration of the physiological side of the subject. While the necessity of some study of types is recognized, very cogent and just criticisms are made of the extreme "type course," criticisms, indeed, which apply not only to biology as taught in schools, but also as taught in colleges.

The starting point for a botanical course will always be a moot

[1] Lloyd, F. E. and Bigelow, M. E. *The Teaching of Biology in the Secondary Schools.* New York, Longmans. 1904. American Teachers Series. 8vo, viii + 491 pp.

question and must necessarily depend in a measure on the individual teacher and the conditions under which he works. Here the fruit is advocated as the point of departure, from which the student naturally passes to the study of the seed and seedling, till finally the fully developed plant and its organs are all taken up. In connection with the necessary morphological and anatomical study, the physiology and, to an adequate extent, the ecological relations of the plant, are brought out. The author's attitude towards ecology will be appreciated by many, for without in any sense undervaluing its interest and importance he subordinates it so that it is not made the only end and aim of botanical instruction. The consideration of types follows, but the transition seems a little abrupt from what has gone before. Whether, in the time usually available in schools, the students could with advantage study such obscure forms as Myxomycetes, must be a question.

The value of the book as a whole, to teachers, particularly to those who have not had the advantage of adequate preparation, cannot but be great. It is essentially not a book which deals with fads, the importance of nature study under the conditions which exist is recognized without exaggerating this importance, the use of botanical instruction proper in higher schools is justified with reasonable moderation. The attitude of the author towards essential questions is wholesome and stimulating. While enthusiasm of the best kind is strongly advocated, sentimentalism is frowned upon, honesty of thought and of observation is insisted upon. The dynamic point of view, already referred to, that plants should be considered as living organisms and not merely as aggregations of cells and tissues arranged in interesting patterns, or as objects to be placed in hard and fast categories, will undoubtedly serve to stir up those who tend to fall into a too formal conception of botany ; and the need of such stimulus when the great mass of botanical instruction the country over is considered, is probably almost as great as ever. Another point of value is the warning against unreasoning acceptance of teleological and causal interpretations, which bring about false conceptions of the significance of structures. The great value of the book then is in this plain straightforward attitude and the desire to avoid and show others how to avoid, question begging ideas of form and of function. As to the particular form of a botanical course for secondary schools it is not necessary to assume any finality in the arrangement suggested, nor is it necessary for the teacher to follow exactly the plan adopted, to be able to get a very useful stimulus from the book.

Practical notes as to laboratory equipment and so forth, conclude Professors Lloyd's part of this volume and it should also be mentioned that at the head of each chapter copious and usually pertinent references are given to articles and books which the reader may desire to consult.

The second part of the book, entitled "The Teaching of Zoölogy in the Secondary Schools," covers some 248 pages arranged under twelve chapters, and is by Professor Bigelow. In the first chapter the aims of zoölogical teaching are discussed from the standpoint of the secondary school and emphasis is laid on the importance of zoölogy as a means of training the mind as well as an informational subject. In discussing available matter for zoölogy Professor Bigelow advocates a partial return to the study of internal anatomy, including dissection, from which in the last ten years the secondary schools have tended to withdraw. It is questionable whether this proposal is sound, for, notwithstanding laboratory pretensions, the teacher of zoölogy is bound to impart most of his knowledge by authoritative statement rather than by demonstration and hence he may draw his laboratory material from the many illustrations in external anatomy rather than from internal dissection so often objectionable to the pupil.

The importance of animal ecology, classification, embryology, palæontology, and evolution are reasonably urged but with the final apology that perhaps these aspects of zoölogy, good in themselves, are for want of time not possible in the school. If, however, we understand Professor Bigelow aright the pupil is not to be treated in such a way as to bring him to the state of a "finished" product at the end of his school life, but he is to be turned out with a mind trained for mental work and awakened by a flood of suggestions that will lead him in later years to take an active interest in the intellectual life about him. From this standpoint few subjects are more important than ecology, palæontology, and evolution.

Good advise based upon actual experience is contained in the chapter on laboratory method, and the advantages of the "verification" and "investigation" methods are set forth so well that even the strongest advocates of the latter must see that theirs is not the only path to true knowledge. The conception of school "physiology" as a special application of zoölogy and its importance in connection with this science is justly emphasized and ought to lead to a radical reform and betterment in the teaching of this subject. The zoölogical text, like that of the botanical portion, is accompanied by copious

references and list of books, a feature which alone makes the volume of great importance to the teacher.

One feature in the present situation of biological teaching is apparently not dwelt upon and that is the importance of high grade teachers for such work. Doubtless this is taken for granted, but it is certainly too true that the subjects included under biology are often forced as side work upon uninterested teachers with the result that the poor outcome is too frequently attributed to the subject rather than to the conditions under which it is taught. As a whole the volume is an unusually sound body of suggestion and advise which no teacher of school biology can afford to be without.

R. & P.

ZOÖLOGY.

A New Textbook of Zoögeography.[1] — Professor Arnold Jacobi of the Forestry Academy at Tharandt, Saxony, has lately published a small manual. It is with much pleasure and satisfaction that we have read this little work, since it is the first general treatise of the subject which pays due attention to the modern improved ideas with regard to zoögeographical methods.

While all previous textbooks on this subject generally fall more or less in line with Wallace's method, giving chiefly an account of the present conditions of animal distribution upon the earth's surface, and being satisfied with the creation of a "scheme" of animal distribution, Jacobi makes it the fundamental idea of his book, that the creation of "schemes of distribution" is not the final goal of zoögeographical research, but only a means to facilitate it. He adopts the view that no scheme whatever is able to explain all cases, that it is possible to create different schemes for different groups of animals, and that even then there are exceptional cases, which need further research. That these exceptional cases very often find their explanation in the geological history of the particular group to which they belong, is also maintained by him, and he most emphatically declares this latter study the most important branch of this science. Thus he fully accepts the general principles of zoögeography as set forth repeatedly by Ortmann.

The limited space alloted for the work made it impossible for the

[1] Jacobi, A. *Tiergeographie* (Sammlung Goeschen). Leipzig, 1904. 12°. 152 pp., 2 maps.

author to give more than a mere sketch. But in this short sketch is condensed a wealth of information that is of highest value for the student. Only a few words shall be said here to direct attention to the chief features of the book.

The whole is divided in three main divisions: the *first part*, introduction, contains the discussion of general principles, part of which has been mentioned above. The two other parts are entitled: *General Zoögeography*, and *Special Zoögeography*. The *former* treats (in 9 chapters) of the general laws of animal distribution, the relation of the range of animals to space, the means of dispersal and barriers to it, the struggle for space, the difference between centre of origin, areas occupied later on, and areas of survival. Further, the principal physical conditions of life and conditions of dispersal are discussed, and finally certain typical cases of distribution are selected as examples for the laws laid down.

The *last part*, Special Zoögeography (17 chapters), contains first a short historical sketch of the work done previously in this line. Then follows a discussion of the schemes proposed for the division of the earth in zoögeographical unites, a discussion of the scheme accepted in this work (for continental life), and a sketch of the actual distribution of selected groups of animals (Mammals, Birds, Reptiles, Amphibians, Freshwater Fishes, Insects, Land Snails, Earthworms). The last chapter treats of marine life and the laws of distribution governing it.

It is only to be regretted that the author did not have an opportunity to more fully discuss certain points, and chiefly, to go into detail with regard to the geological development of the present condition of animal distribution: but lack of space explains this. Another exception might be taken with reference to the scheme accepted for the distribution of land animals: but since this point is to a degree a matter of personal taste with the author, we shall not discuss it here.

A. E. O.

Watchers of the Trails.[1] — Prof. C. D. G. Roberts' latest collection of animal stories, *The Watchers of the Trails*, does not fulfill the promise of his earlier *Kindred of the Wild*. It suggests rather the endeavor to work up the poorer ore from a once rich vein. We can not be expected to follow the fortunes of a dragon-fly larva with the same interest that held us in the story of the bull-moose, the "King

[1] Roberts, C. G. D. *The Watchers of the Trails.* Boston. L. C. Page & Co. 1904. 8vo, pp. 161. With many illustrations by Charles Livingstone Bull.

of the Mamozekel." The only distinctly new point of view in the volume under discussion is the study of domestic breeds in a wild environment. "The Alien of the Wild," describes the fortunes of a bull who is born and reared in the wilderness. London has however already entered this field in *The Call of the Wild.*

In Prof. Roberts' earlier volume there is an interesting essay on the evolution of the animal story, a sort of *confessio religionis* of the literary naturalist. We quote two sentences. "They [the naturalists of the new school] are minutely scrupulous as to their natural history, and assiduous contributors to that science. But above all they are diligent in their search for the motive beneath the action." It is significant that Prof. Roberts, to judge from this essay, seems unacquainted with the school of which Hudson (*The Naturalist in La Plata*), and Belt (*Naturalist in Nicaragua*) are noteworthy examples. The present volume contains a prefatory note in which Prof. Roberts replies briefly to the charge, made by Burroughs, "of ascribing to my animals human motives and the mental processes of man." This prefatory note is an important contribution to the literature of the animal story controversy, inasmuch as it reveals the fundamental difference in temperament between the scientist and the literary artist. Prof. Roberts claims that a boyhood spent at the edge of a great wilderness fits a sensitive, sympathetic nature to portray wild life truthfully. It certainly has fitted him to call up in his fellow-men the mood which he himself experiences in the forest gloom. It does not necessarily fit him to tell us how the animals themselves feel. Whether in this particular volume, he has always, as he claims, been at particular pains to guard against ascribing motives on insufficient evidence, it is impossible to prove one way or the other. But when we read (p. 140) that all the wild kindred near a lumber-camp, which had spoiled their hunting, despised the camp dog as a renegade and traitor, and that they would have felt more satisfaction in taking vengeance on him than on his masters, we wonder how Prof. Roberts knows their minds so intimately. That the dog was killed by a wild-cat seems to have been the only fact in his possession. He says that the wild-cat went off, "elated from his vengeance." Most juries of scientists would, we fear, sustain Mr. Burroughs' charges.

For Prof. Roberts' skill as a literary artist we have a great admiration. His story of "The Truce," in the present volume is a thoroughly admirable piece of work. The book is richly illustrated by Charles Livingstone Bull.

Shells of Land and Water.[1] — This work is a diversion from the usual type of conchological publications, the author endeavors to popularize the study of the mollusks by a narrative. A quartette consisting of a professor and three students, take various trips to the "homes" of the land, fresh-water and marine species; these trips are supplemented by frequent visits to the museum, thus in a general way all of the more important groups are studied. Their first excursion is to the "home" of the fresh-water clam, then a day with the snails of the pond, river and brook, followed by a visit to the museum. The homes of the land snails are next invaded and the evening is spent in the snailery. The next chapter is "how snails eat" with figures of radula, jaws, etc. To study the exotic forms the museum is again visited. In the same manner the marine forms are studied, with instructions for dredging and preserving specimens. The work closes with "some books to study" and a glossary of technical terms.

The book contains 175 pages, the illustrations in the text, of which there are upwards of 150, are excellent and well selected, while the eight colored plates are beautiful examples of the three color process; the work is also embellished by six half-tone plates from photographs showing the homes of the various mollusks. To those taking up the study of conchology as a pastime the work is admirably adapted.

C. W. J.

BOTANY.

Pfeffer's Plant Physiology. — The completion of the second edition of Pfeffer's *Pflanzen physiologie*[2] is a significant event. Ten years ago Pfeffer began the revision which has just been completed. It would have been finished earlier but for the continued ill health of the author. Pfeffer's aim, as pointed out in reviews of the parts which have previously appeared,[3] has been to present the science as

[1] Baker, F. C. *Shells of Land and Water. A familiar Introduction to the Study of Mollusks.* Chicago, Mumford, 1903. 8vo, xii + 262 pp., 215 figs.

[2] Pfeffer, W. *Pflanzenphysiologie. Handbuch der Lehre vom Stoffwechsel und Kraftwechsel in der Pflanze.* 2 te Auflage, 2 vols., Leipzig, Engelmann, 1897–1904.

[3] *American Naturalist*, vols. XXXII, pp. 450–1, 1898, and XXXVI, pp. 594–5, 1902.

it is at present, to separate fact from theory, to examine each hypothesis, discarding the false and emphasizing the probably true. Besides the enormous amount of reading required, Pfeffer and his assistants have done a great deal of experimental work, testing in his own laboratory the work and conclusions reported by others. The result is a critical mastery, on Pfeffer's part, of the whole subject of plant physiology, such as no other man possesses, and the fruit of this mastery is his book. The book, in presenting the science as it now is, shows what is known and thought, how much more this is than when the first edition was published nearly twenty-five years ago; it shows also how indefinite our knowledge is, how inadequate our thoughts, and how limited the field of investigation has hitherto been. As remarked in a previous review, the plant physiology of to day is the result of the study of higher plants mainly. The lower plants have been more carefully studied by physiologists during the last five years than ever before. The results of this study are evident and valued. When the physiology of these plants is understood even to the extent to which we now understand the physiology of higher plants, plant physiology will bear a different aspect from what it does to-day. In the second as in the first edition, Pfeffer divides his subject into *Stoffwechsel* and *Kraftwechsel*. To these classical headings a third is now sometimes added, *Farmwechsel*. Though this last is but a special aspect, a special result, of the other two, it is a result which will certainly become increasingly important as it becomes increasingly evident from the experimental investigation of simpler plants.

From Pfeffer's book it is clear that the study of the influence of the various factors of the environment upon the form of living organisms stands, in results, far behind our knowledge of these factors upon the immediate behavior of living organisms. In this last part of the *Handbuch* we have mainly the subject of movements. These are examined in detail. The mechanics of movement are better understood than the action of the stimulus upon the living organism, but in both cases the phenomena are so complicated and often so contradictory in different forms that it is impossible to make a general statement of the subject which would be both clear and truthful. For this reason this part of Pfeffer's book possesses in the extreme those qualities for which the earlier parts have been most severely criticised, *viz.*, lack of definite summary statements, repetitions, and minute argumentative criticism. Summary statements which would be true cannot now be made. Repetition is unavoid-

able because of the original division of the subject, but it is always a repetition from a different standpoint, giving the reader a more comprehensive view of the subject. And only by minute criticism of what has been published is it possible to distinguish fact from theory, and well-founded theory from that which is only plausible.

This book will serve as the basis, the inspiration, and the critical guide of the investigations of the next twenty years. The future is not likely to give us another book by one man who is master of the whole field. This book stands as a monument to Pfeffer's learning. The books which follow it will be written by several masters working together, as is already the case in animal physiology.

It may not be out of place to mention here that the Philosophical Faculty of the University at Göttingen have awarded the 12,000 mark prize of the Otto Vahlbruck Foundation to Pfeffer, justly considering his *pflanzenphysiologie* the most worthy contribution to botanical science which has been made in years.

The excellent English translation by Ewart, the first two parts of which have appeared,[1] will be cordially welcomed when completed.

G. J. P.

[1] Published by the Clarendon Press, Oxford.

CORRESPONDENCE.

Editor of the American Naturalist.

Sir: — I have only recently seen in the *American Naturalist* for July–August the review of a revision of Professor Orton's *Comparative Zoölogy* which I prepared and which was issued last year by the American Book Company. As the reviewer makes certain very erroneous implications I am led to send this communication with the request that you permit it to appear in the *Naturalist.*

About ten years ago at the request of Mrs. Orton I made a revision of Professor Orton's *Comparative Zoölogy* which was published by Harper and Brothers. In this edition it was impracticable to reset the book, and all new matter, except verbal changes, was placed in an appendix. This edition, I understand, is still in use in some schools and is known as Orton's *Comparative Zoölogy*, revised by myself.

More recently, at the request of the American Book Company and with the cordial approval of Mrs. Orton, I prepared the edition which is the subject of the review mentioned. This revision was undertaken largely for the purpose of meeting the wishes of certain schools that desired to continue using Professor Orton's book but felt the necessity of introducing practical work, of following a more modern system of classification, and of having a more logical arrangement of the text than the earlier edition afforded. When deciding upon the title for the new revision the publishers contended that it must be so worded as to avoid the confusion which would inevitably arise in the schools and in the trade if the two editions bore the same title, it being their intention to continue the publication of the earlier revision. For this reason the name was changed to *General Zoölogy, Practical, Systematic, and Comparative. Being a Revision and Re-arrangement of Orton's Comparative Zoölogy* a title which fully describes the character of the book. From the letters which passed between the publishers and myself regarding the title, I quote from one concerning a form of title-page which was submitted to me but which I rejected because it did not express fully enough the fact that the present edition claims to be nothing more than a revision. "As to having my name standing practically alone

as the author of the book, I have very strong conscientious scruples against it. The book, even as it stands, is really Orton's work, for I have added only a comparatively small amount, and I do not want to appear to have appropriated another man's book. But this, I fear, is just how it will look unless Orton's name is given, as it deserves, more prominence on the title-page. If I had re-written the book, then we might say, perhaps, 'Based on Orton's Comparative Zoölogy,' but, as matters stand, the book *is Orton's Comparative Zoölogy*, with some changes and additions of my own, to be sure, but they are hardly sufficient in number or importance to warrant me in assuming to have made such a radical change as to justify my being called the author." In the same letter I suggested that in order to avoid confusing the two editions the trade name for the new one might be the "Orton-Dodge General Zoölogy." The first printing of the book was sent out without Professor Orton's name on the cover, a most unfortunate error and one which no one regrets more deeply than I do, but the omission was made without my consent or knowledge and I am in no way responsible for it. The publishers promptly corrected the mistake at the next printing of the volume.

In justice to the American Book Company I wish to state also that to the best of my knowledge the advertising matter sent out regarding the book has never represented it to be "a *new* one," as the reviewer would have us believe. I have carefully examined all of the several catalogues, folders, etc., in my possession and all state that this is "a revision and re-arrangement of Orton's Comparative Zoölogy," and describe fully the extent and character of the changes made. Furthermore, in various expressions attention is called to this fact no fewer than three times in a preface of less than that number of pages. It is, consequently, a most preposterous supposition that anyone can be misled as to the nature of the book.

Finally, if, in spite of all efforts to the contrary, I have not made my position clear, I will say for the sake of those who may be interested in the matter that I deny most emphatically the implication that I have or have had any desire, intention, or expectation to receive credit which properly belongs to Professor Orton, my sometime predecessor in this institution.

Very truly yours,

CHARLES WRIGHT DODGE.

UNIVERSITY OF ROCHESTER.

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IN THEIR WIDEST SENSE

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THE

AMERICAN NATURALIST.

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THE BONES OF THE REPTILIAN LOWER JAW.

J. S. KINGSLEY.

As is well known, the lower jaw in the Reptilia consists of a number of bones to which, eighty years ago, Cuvier gave names, repeating the descriptions with slight alterations in the second edition of his work on fossil bones (1836). He described the elements in the jaw of crocodiles, tortoises, lizards, and snakes, in the order named. Since his day different anatomists have altered these names for various reasons or have applied them to different bones from those to which they were originally given. It has recently become necessary, in connection with some investigations, to revise the nomenclature of these elements, the results of which are given below. Williston has recently pointed out the necessity of some changes.

Cuvier recognized, at most, six bones to which he gave the names articulaire, surangulaire, angulaire, complementaire or coronoidien,[1] operculaire, and dentaire. These were given English forms by Owen, who changed the names of two. The operculaire he renamed the splenial so as to avoid confusion with

[1] He refers to an earlier work by Adrien Camper (*Ann. Mus. Nat. Hist., Paris,* xix, 1812) for a previous use of the term coronoidien, but Camper merely refers to the parts as the *apophyses coronoides.*

the operculum of fishes, while for the complementaire he adopted the alternative coronoid because of its resemblance to the earlier named coronoid process of the mammalian jaw. Other names have been changed by other authors.[1] Thus Wagner calls the articulare the *pars angularis*, the dentary the *pars alveolaris*, the angulare the *p. complementaris posterior*, the splenial the *p. comp. anterior*, and the surangular the *p. comp. exterior*, while Brühl calls the splenial the marginale ; the surangular and the coronoid, the ecto- and endo-complementare. Baur (*Anat. Anz.*, xi, 1896) has attempted to homologize these bones in different reptiles, but it would seem that he has fallen into one or two errors, by taking the turtle rather than the crocodile or the lizard as his basis. As will be seen below there is practical unison in the use of terms by Cuvier in both crocodile and lizard while the turtle exhibits some differences, and again, to use the turtle as the basis would introduce no little confusion into the literature. So I have adopted the lizard as the basis of my work.

Practically all authors are agreed upon two of the elements, the dentary and the articulare, the first forming the anterior bone of the lower jaw, the latter being developed by ossification in the posterior part of Meckel's cartilage and forming a bone by which the lower jaw is articulated with the quadrate.

In an embryo of the lizard Sceloporus in which the centers of ossification have appeared, reconstruction from serial sections shows the following elements (Fig. 1). Meckel's cartilage (*m*) is a long, slender, slightly curved cylindrical rod, the cartilages of the two sides being continuous at the symphysis of the jaw. Just in front of the articulation with the quadrate, a strong dorsal process marks the anterior boundary of the articular facet (*a*), the cartilage extending a short distance behind this point.

The most posterior ossification is a long and slender bone (*da*) which extends backwards nearly to the posterior end of the meckelian. Behind, it lies on the lower inner surface of the cartilage, but farther forward it rises on the inner surface.

[1] No attempt has been made to find all the terms employed, or to trace each to its earliest use.

Later this element fuses with the bone ossifying in the posterior end of the meckelian, thus forming a part of the articulare, which, as is well known, consists of both cartilage and dermal constituents in the Lacertilia. For this dermal element, which in some reptiles is distinct throughout life, I have adopted the term dermarticulare.[1] Its characteristics are its position on the posterior inner side of Meckel's cartilage, its inferior margin being overlapped by the angulare and its anterior end, which lies ventral to the coronoid, by the splenial element next to be described.

The angulare (*an*) lies on the ventral surface of Meckel's cartilage, its posterior end reaching to about the middle of the dermarticulare, the lower margin of which it overlaps. The splenial (*s*) lies on the inner surface of the meckelian, its posterior end overlapping the anterior end of the dermarticulare. The coronoid (*c*), which lies on the inner side of the jaw dorsal to the splenial and the anterior end of the dermarticulare, needs little description.

On the outer side of the jaw are the dentary and the surangular bones. The dentary (*d*) occupies the anterior two thirds of the jaw, bending below the meckelian so as to be visible beneath it from the inner side, while above, it makes a broad in-curved and down-curved plate, the future alveolar surface. The surangular (*sa*) lies in the posterior third of the jaw, extending backwards behind the articulation but not quite to the posterior end of the meckelian, while below it hardly reaches the ventral border. Its upper margin arches in a broad curve above the meckelian from which it is separated by a large space.

The changes involved in the future development are extensions of all the bones so that the meckelian is covered on both inner and outer surfaces and in the coössification of articulare and dermarticulare to a single element (Figs. 2, 2a). It will be seen that these parts agree in names and positions with those described by Cuvier. The only difference between his account and that given here is the recognition of the dermarticulare as a

[1] This term has been used in the ganoids by van Wijhe. In some instances the element he has so called is clearly homologous with the dermarticulare of the reptiles but in others (Amia) it is a different form.

distinct element, the existence of which has been noted, although no name has been given it, by later writers. The problem is to homologize these elements with those found in the lower jaw of other reptiles, in some of which Baur believed that he had discovered a distinct bone which he has called the presplenial.

In the mosasaurs (Fig. 3) the matter is simple. Here dermarticular (*da*) and articular (*a*) have united into a single bone, the anterior splint of which occupies exactly the position,— below the jaw behind, rising to its inner surface in front,— that the dermarticulare does in the Sceloporus embryo. The splenial (*s*) is greatly enlarged and extends far forward on the inner surface. The other bones call for no comment, except that the surangular (*s. an*) bends inwards over the meckelian in the way described for the lizard.

Baur begins his account with a description of the turtle Emydura (Fig. 4) in which he recognizes his presplenial, but I am compelled to think that here he has fallen into error. On the inner side of the articular (*a*) is a long splint-like bone which passes forward and upward on the inner side of the jaw (*da*). This Baur interprets as the angular. In its position it clearly corresponds to the dermarticulare which has failed to fuse with the articulare proper. Below this is a bone as evidently the angulare (*an*) but which Baur is compelled to call the splenial. Hence, according to him, the true splenial (*s*) which occupies the same position as in the lizard, is an additional element, the presplenial. Baur's mistake[1] thus had its foundation in his identification of the dermarticulare as the angulare although he expressly recognizes the fact that in the Lacertilia the articulare is composed of chondrogenous and dermal elements.

In the ordinary turtles, of which the snapping turtle (Chelydra) may be taken as an example (Fig. 5), the splenial is lacking, the angulare (*an*) extends back to near the posterior end of the jaw, while the dermarticulare (*da*) forms a very large plate on the inner surface, reaching forward to just beneath the coronoid process (*c*).

Baur has also described and figured the jaw in Sphenodon

[1] Baur merely repeats the wrong identification of Cuvier.

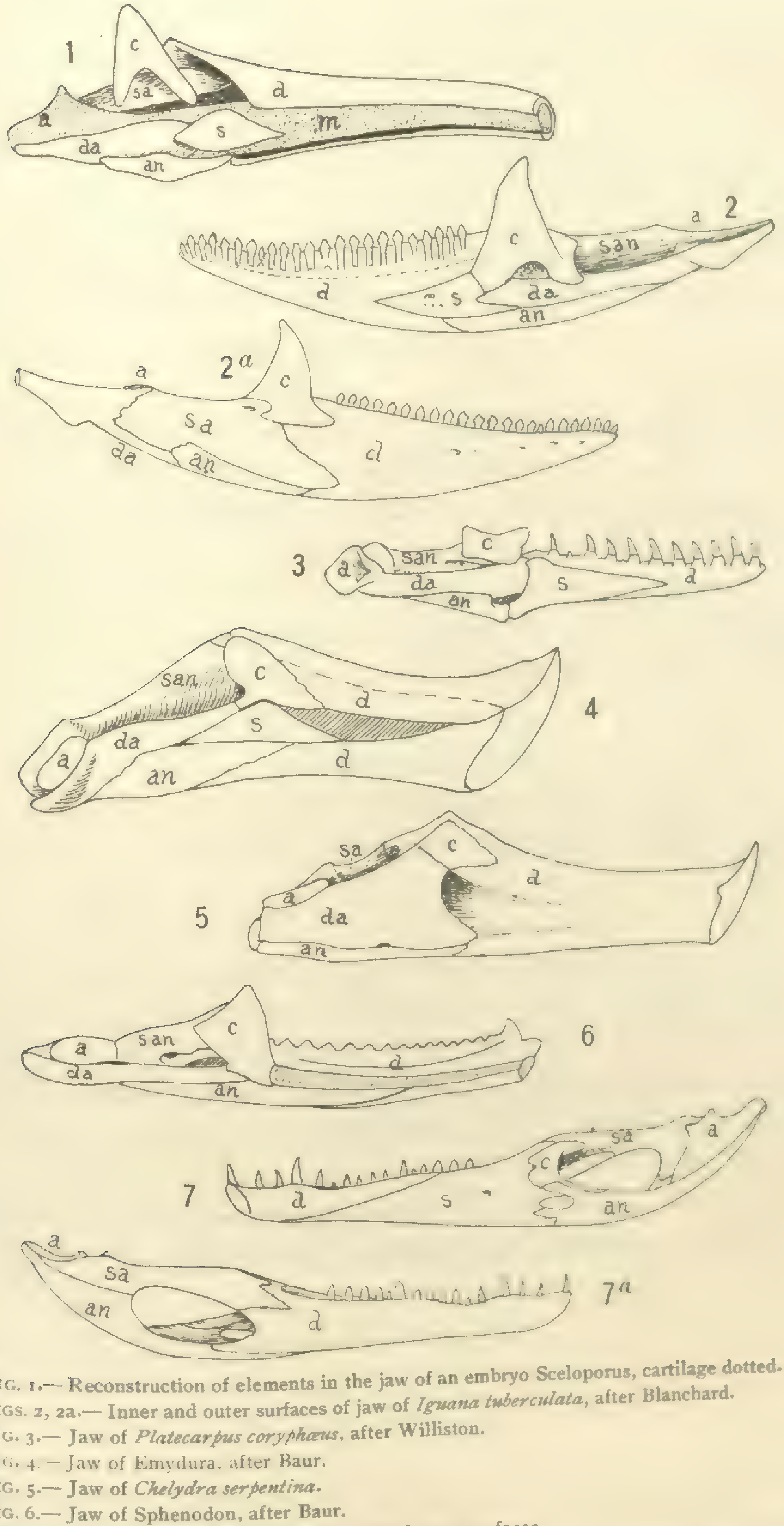

FIG. 1.— Reconstruction of elements in the jaw of an embryo Sceloporus, cartilage dotted.
FIGS. 2, 2a.— Inner and outer surfaces of jaw of *Iguana tuberculata*, after Blanchard.
FIG. 3.— Jaw of *Platecarpus coryphæus*, after Williston.
FIG. 4. — Jaw of Emydura, after Baur.
FIG. 5.— Jaw of *Chelydra serpentina*.
FIG. 6.— Jaw of Sphenodon, after Baur.
FIGS. 7, 7a.— Jaw of *Alligator lucius*, inner and outer surfaces.
a, Articulare; *an*, Angulare; *c*, Coronoid; *d*, Dentary; *da*, Dermarticulare; *m*, Meckel's cartilage; *s*, Splenial; *sa*, *s. an*, Surangulare.

(Fig. 6), and his identifications are adopted by Howes and Swinnerton. Yet it seems probable that here again the dermarticulare (*da*) has been termed the angulare and the angulare (*an*) the splenial. Judging by Günther's figures, which do not agree with that of Baur, it is possible that the angulare is an angulosplenial as he suggests, but the observations of Howes and Swinnerton show no separate elements. The articulare cannot be a compound structure like that in the Lacertilia, for, in the development no dermarticulare, other than that interpreted as such here, occurs.

In the case of the alligator (Fig. 7) I feel less certain. As is well known, besides the articulare (*a*), three bones form the inner surface of the jaw, a bit of the dentary (*d*) being visible near the tip. There can be no question about the coronary (*c*) while the large plate extending forward from the coronoid (*s*) is as clearly the splenial, if the conclusions regarding the other forms studied be correct. The remaining element (*an*) is the more problematical. Baur calls it the splenial and thinks that the angulare is fused with the articulare. It is clearly not the splenial, but it exhibits characteristics of both angulare and dermarticulare, being like the dermarticulare in its articulation with the coronoid, but like the angulare in the rest of its extent. There is no separate bone on the inner side of the articulare and there is a large gap in front of the articulare, extending to the coronoid, which in all other forms is occupied by the dermarticulare. Hence until a study of the development shows that this conclusion is untenable I prefer to call it the angulare and to assume that the dermarticulare has failed to develop. It is the angulare of Cuvier.

These comparisons need to be continued into the Ichthyopsida and especially into the Stegocephala and the ganoids where considerable confusion exists.

CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE. E. L. MARK, DIRECTOR.— No. 160.

NATURAL AND ARTIFICIAL PARTHENOGENESIS.[1]

ALEXANDER PETRUNKÉVITCH.

WITH the discovery by Oscar Hertwig, in 1875, of the essential nature of fertilization as the union of the nuclei of the two parental germ-cells, the line of research in the branches of biology dealing with reproduction became more clearly defined. While on the one hand this discovery put an end to all guess-work, on the other hand it threw light on the part taken in development and heredity by both egg and sperm. To this was added later the knowledge of the behavior of the centrosomes in fertilization, the whole bringing us nearer to an understanding of the otherwise incomprehensible phylogenetic separation of living beings into two sexes, impelled by the necessity of amphimyxis. Again, the theory of the individuality of the chromosomes and the study of the process of reproduction in maturation afforded us an insight, incomplete though it be, into those forms of reproduction which are not accompanied by fertilization. New questions were gradually evolved, but since they had their source in facts recognized by everyone, they were so precise, that when, five years ago, I entered upon the study of parthenogenesis in the honey-bee, I had before me a very definite problem.

All this I purposely mention here. By the time I had published the first part of my research and had gone on in the study of natural and artificial parthenogenesis, there began to appear objections not only to the results of my own work, but even to statements hitherto undisputed, as well as to the most sober interpretations of facts. These objections were raised

[1] Read before Section F — Zoölogy — of the A. A. A. S. at the 54th annual meeting in Philadelphia, 1904.

not only by people unacquainted with the facts won by science and with the methods of scientific research, as bee-keepers for instance, but also by men of very considerable scientific education, especially physiologists. It seems to me therefore seasonable to review briefly these objections, in order to determine what, if anything, has been gained through this controversy, so that we may know how the question of parthenogenesis now stands.

Our knowledge of fertilization and parthenogenesis, acquired in the study of many different animals, may be recapitulated in the following words:

1. Both the egg ready for fertilization and the mature sperm show a reduction in the number of chromosomes of their nuclei to one half of that found in somatic cells.

2. No matter how many spermatozoa succeed in entering the egg, the nucleus of only one of them, under normal conditions, fuses with the egg-nucleus, thus restoring the chromosomes to their original number. All other spermatozoa are absorbed.

3. The centrosome of the egg disappears after the second polar cell is formed, its functions being assumed by the centrosome of the spermatozoön.

4. In most parthenogenetic eggs no reduction of chromosomes takes place — only one polar cell being formed — and the egg-centrosome remains active.

Now, all of the objections alluded to above are directed against one or more of these four propositions. As, however, it is in these propositions that our present understanding of parthenogenesis is epitomized it is of urgent importance to discover how much of truth these objections contain.

First of all I shall consider the objections brought forward by the physiologist Bethe and the zoölogist Bresslau. Both claim to find the essence of fertilization not in the union of the sperm-nucleus with the egg-nucleus, but in the entrance of spermatozoa into the egg. Bethe (:04) says explicitly: "I consider an egg fertilized when a spermatozoön has entered it. What becomes of this spermatozoön later on is another question." He says, further, that not alone the chromosomes of the nucleus enter the egg, but also other substances, of whose fate we know

nothing, and that we keep in sight a part, only, of the whole phenomenon when we speak of fertilization as the union of nuclei. Bresslau (:04) supports nearly the same view, and distinguishes between "Besamung," or the entrance of spermatozoa into the egg, and "Befruchtung" or fertilization in the sense of Hertwig, Weismann, and others, *i. e.*, the union of the nuclei.

In one respect Bethe and Bresslau are right, that is, as to the necessity of distinguishing between these two phenomena; but it remains to decide which of the two phenomena exerts the greater influence upon the development of the egg and may therefore be considered the one essential to fertilization. This question seems to me easy of solution in the light of recent experiments and observations. There can exist no doubt as to the importance of the union between sperm- and egg-nuclei. The normal number of chromosomes is indispensable to normal development. The paternal hereditary characters are transmitted to the descendant by the chromosomes of the sperm-nucleus. Even if the protoplasm of the spermatozoön, in those cases where it succeeds in entering the egg (for it is frequently cut off by the suddenly formed yolk-membrane), should possess the power of transmitting by heredity certain paternal qualities, yet, in the presence of the egg-centrosomes, it loses that power. Nor can there be doubt as to the importance of the part taken by the sperm-centrosome. It gives the stimulus to development and controls the successive divisions. Without it there can be no development; when hindered in the normal performance of its functions, abnormal development results.

We now turn our attention to the phenomenon of the entrance of spermatozoa into the egg. Does it make any difference in the development of an egg whether one or several spermatozoa enter it? No, for the nucleus of only one spermatozoön is destined to unite with that of the egg. In those cases where polyspermy exists normally, all spermatozoa with the exception of one are gradually absorbed by the egg-protoplasm, and the resulting development is the same whether the spermatozoa are many or few; but when, as sometimes happens, they are not absorbed by the egg-protoplasm, their centrosomes form independent centers for cell-division, thus interfering with the nor-

mal development of the egg, and sometimes even proving fatal. Abnormal development also follows where the egg-nucleus unites with more than one sperm-nucleus.

Thus the entrance of a spermatozoön into an egg cannot be regarded as in itself the efficient stimulus to normal development. Moreover, it is possible by etherizing an egg, to prevent the union of the sperm-nucleus with the egg-nucleus. By this means one half of the egg, that containing the egg-nucleus, develops parthenogenetically, while the other, containing the sperm-nucleus, develops merogenetically. Knowing all this, one must realize that the simple fact that a spermatozoön has entered an egg is relatively unimportant, though it is of course a necessary step in fertilization, rendering possible the union of the two pronuclei.

I consider it therefore perfectly correct to hold to the old definition of fertilization and to call an egg fertilized only when the union of the nuclei is accomplished. This definition does not take into account the behavior of the centrosomes, and rightly, since these constitute only the stimulus and the controlling apparatus of division and are not as important as the chromosomes, *i. e.*, whether the division is accomplished through the influence of the egg-centrosome, or that of the sperm-centrosome, does not change the outcome of the union of the pronuclei.

Applying the same standard to a definition of parthenogenesis, we should expect to say that the latter represents development without fertilization; yet we shall see that such a definition is too broad and that in order to avoid misunderstandings it is necessary to restrict it in certain points.

Development without fertilization takes place normally in many animals of different groups. Leaving out of consideration reproduction by the division of the whole animal, we find these three kinds of propagation: parthenogenesis, pædogenesis, and budding. Under budding we understand development through successive, regular mitotic cell-divisions, proceeding from one or several cells. Parthenogenesis is always development of an unfertilized egg and is introduced by a maturation process, while the nature of pædogenesis is not yet known. The facts that pædogenesis occurs in only a few animals and

that these animals are very rare, make its study exceedingly difficult. We know no more now than was contained in the work of Metschnikoff on Cecidomyia, the account of which appeared in 1865, when the maturation divisions of the egg were still unknown. Should further research show that pædogenesis is also introduced by a process of maturation in the egg, it must then be regarded as a case of larval parthenogenesis. If, on the contrary, the maturation process is wanting in pædogenetic development, it would be more reasonable to place pædogenesis in the same group with budding. In any event it is a problem by itself.

The process of maturation in the egg is without doubt equally indispensable for parthenogenetic development and for that resulting from fertilization; yet there is a great difference between the two, the importance of which was at once recognized by Weismann, its discoverer, many years ago. All eggs requiring for their development fertilization, undergo a double maturation division. This results in the reduction in the number of chromosomes by one half. On the other hand, in the majority of parthenogenetic eggs — the single exception being that of certain insects — there takes place but one maturation division, and in consequence, there is no reduction in the number of chromosomes. In this way the opportunities for variation are much restricted. The exception to this rule is found in those insects in which only one sex develops parthenogenetically, and in the male individuals in those cases where both sexes develop parthenogenetically. In such cases two maturation divisions invariably take place with a corresponding reduction in the number of chromosomes. The insects which on account of the possession of this peculiarity have been much studied lately, are the ants and the bees. In these Hymenoptera it is only the males that develop parthenogenetically. I have every reason to re-affirm this, notwithstanding the recent objection raised against it.

After what I have said about fertilization it is clear that microscopic study, and that only, is able to show without error whether an egg is fertilized or not. The development of an aster around the centrosome of the spermatozoön after the lat-

ter has entered the egg, facilitates the finding of the sperm-nucleus, which keeps its place close behind the migrating centrosome. Were it not for the objections which have been raised by men like Pflüger and Bethe, I should scarcely need to mention that this sperm-aster develops in the same way throughout the entire animal kingdom, that in polyspermic bee-eggs similar asters appear in numbers equalling those of the spermatozoa which enter the egg, and that also in the so-called drone-egg an aster would surely develop, should a spermatozoön enter it. The experiments made upon the eggs of bees, consisting in transporting them from one kind of comb-cell into another, in an attempt to change their sex, have proved to be failures. Should similar experiments, however, some day meet with success, it would only show that it may be possible artificially to change sex.[1] The objection that in drone-eggs the aster might not develop because of the influence of the saliva of the workers which take charge of the eggs as soon as they have been laid, and that in consequence a spermatozoön, though present, might easily be overlooked, does not bear critical investigation. Experiments and microscopic preparations alike showed that the saliva of the workers exerts no such influence. For when fertilized eggs are treated with the same saliva, the aster none the less develops. Or would the opponents of parthenogenesis — who believe that a queen can by no reflex be impelled to fertilize or to inhibit the fertilization of her eggs as she lays them in worker-cells or in drone-cells — be bold enough to affirm that the workers treat the eggs with two different kinds of saliva, corresponding to the comb-cells in which these eggs are laid? Yet this is what the opponents of parthenogenesis claim. How

[1] Experiments in attempting to change sex artificially have been made by vom Rath, by v. Buttel-Reepen, by myself, and by others with negative results. Experiments with apparently positive results have been made and often described by Dickel, a German bee-keeper. I desire here earnestly to warn against the attempt to use in any way whatsoever the experiments of Dickel without first verifying them, as he has on several occasions in his scientific work practiced deliberate fraud in an effort to support his theory, for which delinquency he has frequently been called to account by v. Buttel-Reepen and myself. The history of the falsely labelled bottles containing bee-eggs, together with my exposure of this deliberate trick, made clear the absence of spermatozoa in drone-eggs and thus demonstrated the efficiency of microscopic study.

wonderfully complicated that reflex would have to be which could stimulate to action at a given time only one of three pairs of glands which possess a single duct common to them all!

There are still other difficulties in the way of these objections. The union of the nuclei, not the presence of an aster, is the essential of fertilization. Now, this union of the nuclei may readily be observed, whether the aster lies in the same microscopic section with the nucleus or not, and even when it does not appear at all. Since there is no union of nuclei in drone-eggs, they are not fertilized. As this is the only reasonable conclusion, it sounds strange to hear Pflüger (:03) say that to claim parthenogenesis for the bee, is to adopt a false and insufficiently supported hypothesis, and that the queen-bee is probably a hermaphrodite in which the male sexual glands have not yet been discovered. Still stranger is the contention of Bachmetjew (:03), who says that the right wing of the drone and the left wing of the worker develop parthenogenetically, while the left wing of the drone and the right wing of the worker are the result of fertilization, on the ground that the number of hooks on their wings is subject to variation, displaying two different maxima of frequency. If the theory of partial parthenogenesis can find any support in facts, it is more likely to be applicable to those cases of bee-monsters which exhibit a marvelous mosaic of male and female characters.

If, however, more than one form of parthenogenetic development can with certainty be recognized, should not microscopical research be able to throw light upon the origin of these forms? The answer to this question may be looked for in the behavior of centrosome and chromosomes. There can be no doubt that in parthenogenetic eggs the egg-centrosome remains active, and in *Artemia salina*, at least, we can easily see that it moves alone toward the center of the egg to await there the nucleus, which after the single maturation division, is destined to become the first cleavage nucleus. Thus does the egg-centrosome in parthenogenetic eggs maintain its individuality through all cell generations. In the fertilized egg of bees the centrosome of the spermatozoön becomes the active centrosome and as such passes in turn into the spermatozoön of the next generation. We may

therefore say that in all cases in which either both sexes, or even one sex, invariably develop from fertilized eggs, every centrosome (even that of the egg, which is destined to disappear) is a descendant of a sperm-centrosome — a *male* centrosome, if I may so call it. There is apparently a difference between this and pure parthenogenesis, where every centrosome is a descendant of the egg-centrosome and could be called a *female* centrosome. Does such a difference in reality exist? If we believe with Wedekind (:02) that parthenogenesis is an original, primary mode of development, we must admit that it does. But this would mean that animals which are closely related to each other differ in their phylogenetic origin. Is it not simpler to admit that even in pure parthenogenesis the ostensibly female centrosomes are descendants of a remote ancestral male centrosome? It seems, indeed, as though in animals where fertilization occurs only as a rare exception the males had gradually disappeared yielding to hermaphroditism and parthenogenesis, as Maupas (:00) has so beautifully shown for certain nematodes.

Still more important biological problems are connected with the behavior of the *chromosomes* in parthenogenesis. In pure parthenogenesis only one maturation division takes place and the number of chromosomes remains normal; the individuality of the chromosomes is preserved and thus the questions of variation and hereditary transmission are greatly simplified. Not so in the case of that form of parthenogenesis in which the number of chromosomes is reduced. I have elsewhere (Petrunkewitsch, :02) pointed out that the great difficulties here encountered by the theory of Weismann — which maintains not an essential, but a *qualitative* difference only between the chromosomes — grow out of the cessation of hereditary transmissible variability. There seem to be fewer difficulties in the way of the theory of Sutton and Boveri, — who affirm that the chromosomes are *essentially* different, — since I have shown — and still maintain after a careful re-examination of my sections, in opposition to the objections of Doncaster (:04) — that the number of chromosomes in the first cleavage nucleus of the drone-egg again becomes normal, probably through longitudinal splitting without a corresponding division of the cytoplasm. I thought to find a support for

Weismann's theory in my observation that in parthenogenetic eggs the polar cells, after a copulation similar to that of the pronuclei, give origin through successive divisions to many cells which may be easily traced as far as the gastrulation stage of the embryo. My attempt to trace them still farther and to show that the male sexual glands in bees develop from these cells, has met with much criticism and requires confirmation. Doncaster, however, was able to prove in Nematus the accuracy of my observations as far as the beginning of the blastoderm stage. Although I am still, and until convinced of error shall remain, an adherent of Weismann's theory, I admit that the Sutton-Boveri theory would be strengthened, if it could be shown with certainty that I was at fault in my observations, and that the sexual glands of the drones develop not from polar cells but from the pronucleus. Future research will reveal the truth, but one thing is already certain: in all parthenogenetic eggs hitherto studied, with possibly the one exception of Nematus (according to Doncaster), the number of chromosomes in the first cleavage nucleus becomes in some way equal to that in the somatic cells. This is not limited to animals, but applies equally well to plants[1] and is consequently of fundamental importance. Yet it is not impossible that in Nematus there is no reduction in spermatogenesis, which would lead to the same thing.

It is clear that to reach a solution in the problems connected with the two theories of which I speak, we ought not to limit our research to observation of normal parthenogenesis alone, but rather to supplement such observation by the use of experiment. Here two methods are possible, of which one is cross-breeding and inbreeding, the other, artificial parthenogenesis and merogeny. Much light could be gained by experiments in the former upon animals like the bees, since such experiments would have many advantages over similar ones made on animals developing by fertilization only. Although this method promises much, it has never yet, I regret to say, met with scientific application.

By fertilizing enucleated eggs we obtain development by mer-

[1] Compare the observations of J. B. Overton (:04) on Thalictrum purpurascens.

ogeny, which is characterized by a reduced number of chromosomes, and by the presence of the active sperm-centrosome. In stimulating unfertilized eggs by chemical or physical means to develop, we get what is called artificial parthenogenesis. As I have elsewhere (Petrunkewitsch, : 04) tried to show, this development is due not to a new formation of centrosomes,[1] but to the stimulation to new life of the egg-centrosome, which is otherwise destined to disappear. According as we apply the stimulus before or after the second maturation division, we obtain different results; if before, we get development with the normal number of chromosomes, if after, then with the reduced number. Now, it is interesting that both parthenogenetic development with the reduced number of chromosomes and merogenic development show abnormalities when compared with the development of fertilized eggs. These abnormalities increase in inverse proportion to the number of chromosomes left in the egg, an indication of which is given in the experiments of Stevens, which consisted in a dissection of the fertilized egg in the amphiaster stage into two parts containing unequal numbers of chromosomes. All this goes to show that neither merogeny nor artificial parthenogenesis with a reduced number of chromosomes can be regarded as equivalent to natural parthenogenesis. I call, therefore, these two forms, *artificial, pathological, uniparental development.* On the other hand, artificial parthenogenesis with the normal number of chromosomes leads to apparently normal development. I therefore call it *artificial, true parthenogenesis.*

If we could cause an egg to develop by applying a stimulus before the first maturation division, the gap between parthenogenesis and budding would be filled. Again, if we could bring about artificial parthenogenetic development through several successive generations by stimulating the eggs at the three different moments of their maturation, we might obtain valuable

[1] If there are such *de novo* formations of centrosomes, as seems to be again emphasized by the research of Yatsu (: 04), it is nevertheless probable that in experiments with artificial parthenogenesis, the divisions are due to the egg-centrosome. This being present in every egg, is stimulated to new life, and counteracts possible teratological action on the part of the artificial centrosomes.

results connected with the questions of individuality of chromosomes, determination of sex and variation. These are the problems to which my own study of parthenogenesis has naturally led me and to which I am now seeking solutions in experiments. In this way parthenogenesis, an important problem in itself, becomes at the same time a method for the study of other and greater problems.

BIBLIOGRAPHY.

BACHMETJEW, P.

:03. Ein Versuch, die Frage über die Parthenogenese der Drohnen mittels der analytisch-statistischen Methode zu lösen. Allg. Zeit. f. Entomol., Bd. 8, no. 2–3, pp. 37–44.

BETHE, A.

:04. Entgegnung auf den Aufsatz von v. Buttel-Reepen in Nr. 4 dieser Zeitschrift. Bienenwirtschaftliches Centralblatt, 1904, no. 11, 2 pp.

BRESSLAU, E.

:04. See 'Diskussion.' Verhandl. Deutsch. Zool. Gesellsch., 14. Jahresvers. zu Tübingen. Leipzig, 1904, pp. 66–72, 73–77 *passim*.

DONCASTER, L.

:04. On the Early Development of the Unfertilized Egg in the Sawfly, Nematus ribesii. Proceed. Cambridge Philos. Soc., vol. 12, part 6, pp. 474–476.

MAUPAS, E.

:00. Mode et formes de reproduction des nématodes. Arch. zool. exp. gén., sér. 13, tom. 8, no. 3, pp. 463–624, pl. 16–26.

OVERTON, J. B.

:04. Ueber Parthenogenesis bei Thalictrum purpurascens. Berichte Deutsch. Bot. Gesellsch., Bd. 22, Heft 5, pp. 274–283, Taf. 15.

PETRUNKEWITSCH, A.

:02. Das Schicksal der Richtungskörper im Drohneni. Ein Beitrag zur Kenntniss der natürlichen Parthenogenese. Zool. Jahrb., Abth. f. Anat. u. Ontog., Bd. 17, Heft 3, pp. 481–516, Taf. 11–13.

PETRUNKEWITSCH, A.

:04. Künstliche Parthenogenese. Zool. Jahrb., Suppl. vii, Festschrift Weismann, pp. 77–138, Taf. 8–10. *Also separate*, 62 pp. 3 Taf., 1904.

Pflüger, E. F. W.

:**03**. Ueber die jungfräuliche Zeugung der Bienen. Arch. f. d. ges. Physiol., Bd. 99, Heft 3–4, pp. 243–244.

Also in Münchener Bienenzeitung, no. 20, 1903.

Wedekind, W.

:**02**. Die Parthenogenese und das Sexualgesetz. Verhandl. 5. Internat. Zool. Congr. zu Berlin, pp. 403–409.

Yatsu, N.

:**04**. Aster Formation in Enucleated Egg-fragments of Cerebratulus. Science, vol. 20, no. 521, pp. 889–890.

THE ANGLE OF DEVIATION FROM THE NORMAL VERTICAL POSITION AT WHICH STEMS SHOW THE STRONGEST GEOTROPIC RESPONSE.[1]

JULIA ANNA HAYNES.

Introduction.

Sachs ('82) seems to have been the earliest botanist to pay particular attention to the relation between the angle of deviation in orthotropic plant organs and the strength of the geotropic response. He found, by experiment, that main roots of beans and oak seedlings inclined 8 or 10 degrees from the vertical, slowly or never came into the normal position, while if placed at an angle of 80 or 90 degrees, the growing parts curved 80 or 90 degrees in a few hours. In his "Lectures on the Physiology of Plants," Sachs ('87) also speaks of using in these experiments, thick, rigid, long internodes of such flower-stalks as attain considerable heights in short periods. The results led him to the conclusion that zones of similar developmental stages make various curvatures during the same time if they form various angles with the vertical. That is, the curvature is stronger, the more nearly the angle of deviation approaches to a right angle. If, therefore, this angle of deviation is a right angle, the maximum of growth-difference between the upper and lower sides is attained (Sachs, '74).

Miss Bateson and Francis Darwin ('88) used decapitated flower-stalks of *Plantago lanceolata* and *Brassica oleracea* and found, after numerous experiments, that in both Plantago and Brassica, the greatest curvature was made by the stems placed horizontally, less curvature by those inclined more than 90

[1] Contributions from the Botanical Laboratory of the University of Michigan. No. 85.

degrees, and least curvature in the stalks inclined less than 90 degrees.

Czapek ('95) took up the same line of experimentation as Bateson and Darwin, considering also the point which the other experimenters seem to have neglected, *i. e.*, the latent period of curvature in the various angles of deviation. His purpose was to determine at what angle of deviation it is possible to get the largest angle of geotropic after-effect, "the maximum reaction," for equally long induction periods. To eliminate specific differences, a variety of plants was used: Lupinus, *Faba vulgaris* (*Vicia faba*), Phaseolus, Pisum, and Zea seedling-roots, hypocotyls of Helianthus, and matured internodes of Secale. The general result of Czapek's experiments is given in the statement that the extent of the angle of after-effect curvature increases steadily from the normal vertical position, reaching a maximum at about 45 degrees above the horizontal or 135 degrees from the normal, in the case of roots; 45 degrees below the horizontal, or 135 degrees from the normal, in the case of stems; then falls from that point to the inversely vertical position, 180 degrees from the normal. The horizontal position is not, therefore, according to Czapek, the one in which the maximum reaction takes place.

In spite of his attempts in numerous experiments, even artificially lengthened for the purpose of enlarging small time-differences, Czapek could detect no noticeable difference, as to time of beginning curvature, in stems inclined from 20 degrees to 150 degrees, but in those inclined less than 20 degrees and in those whose angles of deviation were between the optimum for geotropic response and the inverted position, 180 degrees deviation, found a very considerable delay in the beginning of response.

Stone (: 00) experimented with dynamometers, measuring the after-effects of geotropic stimulation and found that in grass-nodes and in the roots of *Vicia faba*, all experiments gave similar results, indicating the horizontal position as that of greatest geotropic excitability. He further found the relationship between nodes at oblique angles and those horizontal to be proportional to the cosines of their angles.

Jost (:02), after making various experiments, agrees with Stone in doubting the validity of Czapek's results.

Just as this paper was ready to send to the publisher, there came to hand a preliminary report by Fitting (:04) in which the author states, among other results, that by a method somewhat similar to mine he has found the strongest geotropic effect when orthotropic plant members were placed in the horizontal position, that is, at 90 degrees from their position of equilibrium.

Because of this division of opinion, and since, in all cases, the experimenters had been led to favor one of the two angles of deviation, 90 degrees or 135 degrees, it seemed that other angles might be neglected and the issue drawn between these two. The present paper reports the results of a series of experiments made in the Botanical Laboratory of the University of Michigan under the direction of Professor Newcombe for the purpose of determining, in a considerable number of plants, at which of these two angles of deviation stems show the stronger geotropic response. Since the earlier work had dealt chiefly with seedling-roots and hypocotyls, the unbranched stems of actively growing young plants were selected as the material for use in most of these experiments.

Method of Alternating Stimulation.

The two general methods used we shall call the "Alternating Stimulation" and the "After-effect" methods. It will be noticed that each differs somewhat from the methods of earlier workers. In all cases, except the first few experiments with Chrysanthemum which were made in the greenhouse where the plants were illuminated on all sides, the work was carried on in a dark-room whose temperature ranged from 20° to 24° C. (18.5° C. in one case).

It is evident that an orthotropic plant stem, if equally stimulated on opposite sides, will remain straight, but if unequally stimulated on the opposite sides, will become curved, and by the direction of its curvature indicate the stronger of the two stimuli. Since it was believed that the response of stems would be greater for stimulation in one of the two positions of

deviation in question than in the other, it was proposed to incline the plants first 90 degrees from the normal vertical position, then 135 degrees from the normal, but in the opposite direction, and to alternate between these two positions giving the same length of time and number of exposures in each, until a decided curve should result.

A special frame, devised by Professor Newcombe, made it possible to experiment with a considerable number of potted plants at one time. This frame was furnished with a hinged rack for holding the pots and this was so hung or supported that by turning it from one stop to another, through an arc of 225 degrees, the plants could be set first at an angle of 90 degrees, on one side of the vertical position, then at an angle of 135 degrees on the opposite side, or *vice versa*, and could be quickly and easily turned from one position to the other with a minimum of jarring.

The stems of the young plants selected were first tied to upright sticks or wires, leaving the upper, growing portions of the axes free to curve, while the weight of the older parts of the stems was supported to prevent all sagging when they were turned out of their normal position. In the case of several seedlings in one pot, all whose hypocotyls were not vertical were cut away at the outset. The pots were then firmly wedged in the frame, care being taken to keep the growing tips upright. When all was in readiness, the frame and its rack were turned so as to bring all the stems into one of the two positions desired, and alternation was begun.

Experimentation.

Young plants of Chrysanthemum, Ageratum, Lavandula, Fuchsia, Heliotropium, and Coleus were used in these experiments; also seedlings of *Linum usitatissimum*, *Raphanus sativus*, *Brassica alba*, and *Helianthus annuus*. The process of alternation was continued from 2 to 7¾ hours according to the sensitiveness of the plants. When a noticeable curve appeared after an equal number of exposures in the two positions, the pots were set upright again and the direction of the stems was carefully noted.

The accompanying figure shows the frame turned on its side to bring the set of young Chrysanthemum plants into the upright position for observation at the close of one experiment. Plants 1, 3, and 4, numbering from the front, show typical curves. Other plants of the set gave equally good curves which do not show distinctly in this view.

During alternation experiments, the frame stands on the base

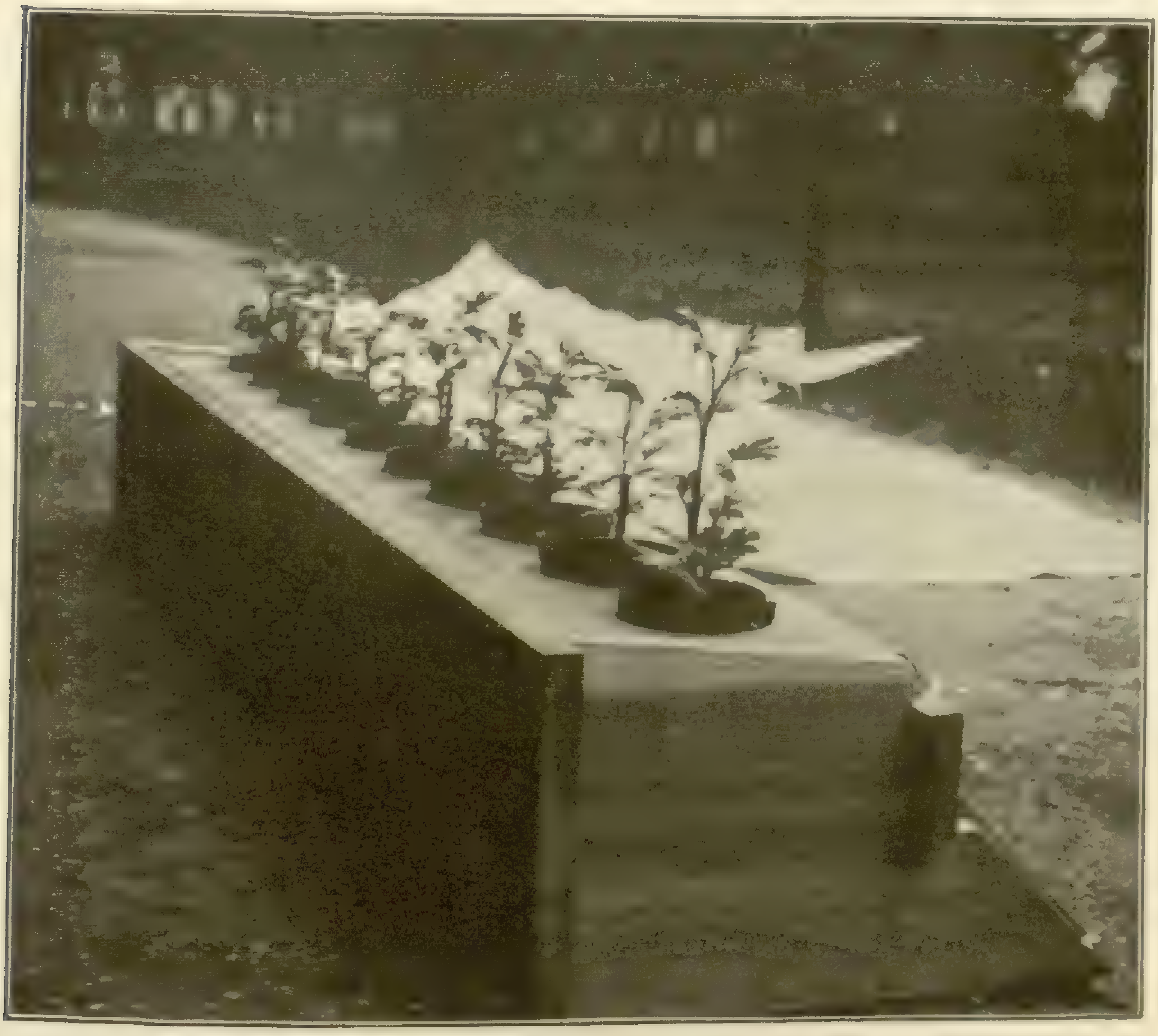

FIG. 1.—Plants in turning-frame. *a*, base; *b*, hinge-line; *c*, stop.

a and the shelf hinged at *b* hangs vertically while exposing the stems at 90 degrees from the normal position, then is turned over to stop *c* to make the exposure at 135 degrees from the vertical.

After experimenting in this way for some time, it was thought that an error might have entered through closing the experiments immediately after exposing the plants in the last position, thus allowing no time for the appearance of its resulting curvature, and, in effect, giving less exposure in one of the two positions than in the other. To remedy this, in the later

experiments the plants were allowed to stand upright for half an hour after the last exposure, before making the final observation. In no case did this modify results in favor of the deviation of 135 degrees, while with few exceptions, the plants, after this treatment, showed more pronounced curves in favor of the deviation of 90 degrees than they did at the close of stimulation. This was true whether alternation was begun from the position of 90 degrees deviation or from that of 135 degrees.

Marked differences in sensitiveness, indicated by the length of time required to produce curvature, were shown not only by plants of widely different genera but by different individuals of the same species and by the same individual at different times.

Of the 395 plants used in these experiments, 53 did not respond in the time given to the experiment, and are simply to be considered less sensitive than their fellows showing curvature. Of the 342 that did curve, 331 or 96.8 % responded better for the deviation of 90 degrees, 11 or 3.2 % only, for the deviation of 135 degrees.

Table I. Results Obtained by Alternating Stimulation.

No.	Material.	Temp.	Time Hrs. Min.	No curvature.	Curvature at Deviation of 90 degrees	Curvature at Deviation of 135 degrees
	Young plants.					
6	Chrysanthemum		2— 0	3	3	0
6	"	13° C	3—20	2	4	0
5	"	18° C	3—20	1	4 2 slight	0
5	"	21° C	3—40	0	5	0
6	"	23° C	3— 0	0	6 1 slight	0
10	"	22° C	7—45	0	10	0
9	Ageratum	20° C	5— 0	0	9	0
5	Heliotropium	22° C	4— 0	0	5 2 very slight	0
7	Lavandula	23° C	3—40	0	7 1 slight	0
7	"	22° C	3— 0	0	7	0
3	"	22° C	2—40	0	3 1 slight	0
10	Fuchsia	25° C	2— 0	0	10	0
10	"	18° C	2—40	5[1]	5	0
9	"	20° C	3—40	0	9	0
9	Coleus	23° C	3— 0	0	7	2 very slight
2	"	22° C	2—40	0	0	2 very slight
	Seedlings.					
8	Linum			3	5	0
150	Raphanus sativus	24° C	2— 0	3	145	2

[1] After standing upright 30 minutes, all were curved in favor of 90 degrees deviation.

Table I.— Continued.

No.	Material.	Temp.	Time Hrs. Min.	No curvature.	Curvature at Deviation of 90 degrees	135 degrees
29[1]	Raphanus sativus	22° C	4 — 0	8	18	3 apparently
22[1]	" "	21° C	6 — 30	7	14	1
31[1]	Brassica alba	22° C	4 — 0	3	28	0
25[1]	" "	21° C	6 — 30	11	14	0
21[1]	Helianthus annuus	21° C	6 — 30	7	13	1
395				53	331	11

Number showing curvature, 342.
Percent of these showing curvature for deviation of 90 degrees, 96.8.
" " " " " " " " 135 " 3.2.

After-effect Method.

By this method, orthotropic plant members are exposed to the one-sided action of gravitation by being placed out of their normal position; but before a geotropic curve has time to appear, the plant is put upon the klinostat and so revolved that the further curving effect of gravitation is neutralized during the revolution. Thus any geotropic influence induced in the plant before the plant was placed on the klinostat has opportunity to manifest itself. If, now, the gravitation effect on plants differs according to the deviation of the plant from its normal position, we may expect the size of the after-effect angle attained on the klinostat to be greatest when the previous exposure of the plant was made at the angle of optimum stimulation. In other words, this method may possibly be used to aid in the discovery of the angle of optimum stimulation.

It was believed that results obtained by exposing stems for the short period to the gravity-stimulus would be more reliable than those of Czapek who forcibly prevented all curvature of the roots and hypocotyls used while exposing them for hours to the action of gravity in each of the two positions, and thus, it would seem, making it possible for the long continuance of a weak stimulus to equal the effect of a stimulus in reality stronger.

[1] Results quoted from Professor Newcombe by permission.

Experimentation.

The plants used in these experiments were prepared as in the preceding series, then fixed on klinostats with stems radial to the horizontal axes of rotation. One half of the number used were inclined 90 degrees, the other half, 135 degrees from the vertical, and both sets were held in position for a time somewhat shorter than the previously determined latent period for geotropic curvature in the species used. The subsequent influence of gravity was then removed by rotation on the klinostats for a time at least twice as long as the period of stimulation, and finally, the pots were set upright and the amounts of curvature made by the plants of the two groups were carefully compared.

The number of individuals, as well as the number of species used in these experiments was smaller, and the results obtained were less satisfactory than in the experiments by the method of "alternating stimulation," but when any difference in after-effects could be observed, it was in agreement with the results of the alternation experiments. Ageratum, Lobelia, Chrysanthemum, and the seedlings of Linum showed greater curvature as the after-effect of stimulation at the angle of 90 degrees from the normal position than at 135 degrees.

Table II. Results by After-effect Method.

Material.	Temperature.	Latent Period.	Time of Exposure.	Time of Rotation.	Greater Curvature for Deviation of
Young plants.					
Lobelia	25.5° C	30 min.	20 min.	40 min.	90 degrees
Ageratum	22.0° C	20 "	15 "	40 "	90 "
Chrysanthemum	22.0° C	30 " +	30 "	60 "	90 "
Seedlings.					
Linum	26.5° C	25 " +	25 "	50 "	90 "

Conclusions.

In conclusion it may be said that both the method of "alternating stimulation" and the "after-effect" method as I have used them in numerous experiments involving a greater number of species than other experimenters have reported, furnish remarkably strong evidence that stems respond better to the gravity stimulus when their angle of deviation from the normal position is one of 90 degrees than when it is one of 135 degrees; and since the question seems to have been narrowed to these two angles by earlier workers, it may further be claimed that the angle of deviation from the normal vertical position at which stems show the strongest geotropic response is one of 90 degrees.

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BIBLIOGRAPHY.

Bateson, A. and Darwin, F.

'88. A Method of Studying Geotropism. Annals of Bot., II, 65.

Czapek, F.

'95. Untersuchungen über Geotropismus. Jahrb. Wiss. Bot., XXVII. 283.

Fitting, H.

:04. Geotropische Untersuchungen. (Vorl. Mittheil.) Ber. Deutsch. Bot. Gesellsch., XXII, 361.

Jost, H.

:02. Die Perception der Schwerereizes in der Pflanze. Biol. Centralbl., XXII, 167.

Sachs, J.

'74. Ueber das Wachsthum der Haupt- und Nebenwurzeln. Arbeit. Bot. Inst. Würz., I, 454.

'82. Ueber orthotrope und plagiotrope Pflanzentheile. Arbeit. Bot. Inst. Würz., II, 240.

'87. Lectures on the Physiology of Plants. English translation.

Stone, G. E.

:00. Geotropic Experiments. Bot. Gazette, XXIX, 136.

NOTE ON VARIATION IN THE RAY FLOWERS OF RUDBECKIA.[1]

RAYMOND PEARL.

In a recent number of this journal (Vol. XXXVIII, pp. 427–429) Mr. F. C. Lucas has published an account of the variation in the number of ray flowers in *Rudbeckia hirta*, the common "brown-eyed Susan." Since attention has been called to the matter in this way, it seems desirable to put on record some statistics on variation in this form collected by the writer.

My material consisted of 430 heads from plants collected at random from a large patch, July 25, 1903. The locality was Farmington, N. H. The plants were growing in an open hay field, on a moderately sloping hillside. The soil was a sandy loam, and on account of the thorough drainage, the ground was decidedly dry. In the counting I was assisted by Mr. Roswell T. Pearl.

The following frequency distribution of ray flowers was obtained:

Number of ray flowers.	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Frequency.	5	11	59	37	42	49	55	121	19	11	10	2	3	1	2	1	0	0	1
Total.	430																		

The frequency polygon is shown in Figure 1.

The mean number of ray flowers here is 11.365. The agreement with Lucas' Lot 4 is very close in all particulars except extent of range. This series gives peaks at the Fibonacci numbers 8 and 13, the principal one being at 13, as in his cases. In this series, as in Lucas' Lots 2, 3, 4, and 5, all the heads on each plant collected were counted. It would appear from a compari-

[1] Contributions from the Zoölogical Laboratory, University of Michigan. No. 90.

son of Lucas' Lot 1 with Lots 2 and 3 or 4 that this procedure tends to give a decidedly lower mean than is obtained from a random sampling of heads directly collected in the field.

A slight typographical error in the paper of Lucas to which

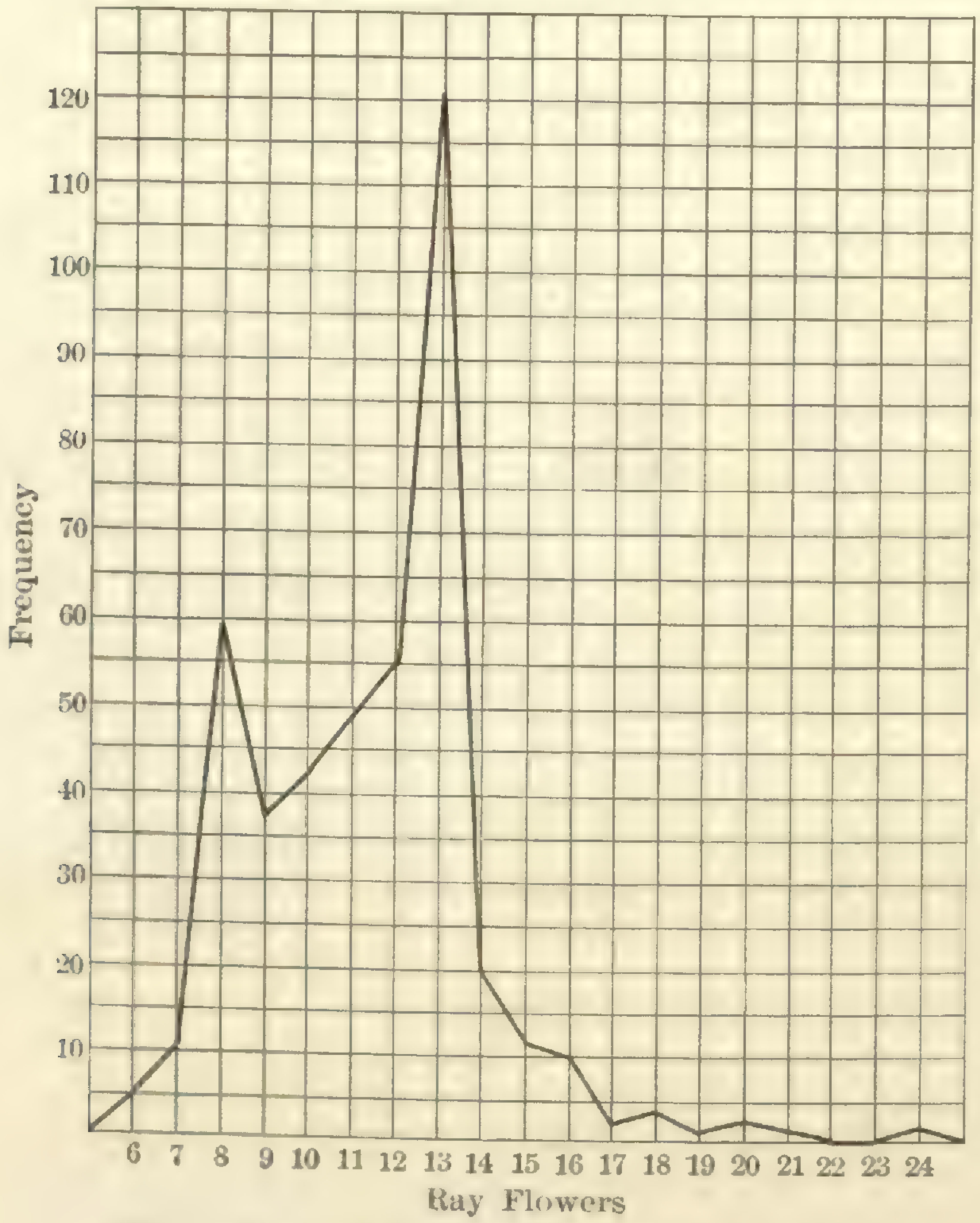

FIG. 1.— Frequency polygon. Ray flowers of Rudbeckia.

reference has been made, was noted. In the legend to Fig. 2 the number of heads in the combined Lots 2 and 3 is given as 468, while in the text Lot 2 is stated to have included 225 heads, and Lot 3, 240 heads.

NOTES AND LITERATURE.

ZOÖLOGY.

The Halictine Bees of America.— Mr. J. Vachal has published the descriptions of a large number of supposed new American bees of the genus Halictus, in the *Bulletin* de la Société Scientifique, Historique et Archéologique de la Corrèze (France), July–September, 1904. As this publication is one not usually seen by American naturalists, it will be useful to give a list of the species, with the localities and some indication of their characters. This information follows herewith in tabular form. I have not thought it worth while, at present, to give the characters of all the Mexican species; but the table clearly separates all those of the United States.

Abdomen with bands of pale hair or tomentum on the apical margins of the segments . . . . 1.

Abdomen with bands or lateral patches of hair or tomentum at the bases of the segments . . . . 4.

Abdomen without distinct bands or spots of pale hair or tomentum on the apical margins or at the bases of the segments, but often more or less covered with fine pubescence . . . . . . 24.

1. Species without metallic tints . . . . 2.
At least the head or the thorax more or less metallic, with green tints . . . . 3.

2. Very large, 14 mm. long (British Columbia) . . . *procerus*, ♂.
Not over 11½ mm., allied to *H. parallelus* Say (Nevada) *denticulus* ♂, ♀.

3. Species of Georgia, New York, Pennsylvania, British Columbia, and Illinois; closely allied to *H. tumulorum* L. . *nearcticus*, ♀, ♂.
Species of South America *ochromerus*, ♀ (Brazil) and *citricornis*, ♂. ♀ (Chili).

4. Abdominal segments black or brown, the margins concolorous . 5.
Abdominal segments with the apical borders more or less testaceous or reddish . . . . 9.

5. Posterior face of metathorax with a distinct, sharp border, at least at sides . . . . 6.
Posterior face of metathorax without such a border, the lateral margins rounded . . . . 8.

6. Smaller, length not over 7 mm. (Mexico) . . . . . *linctus* ♀.
   Larger, length 8 mm. or more; females . . . . 7.
7. Species of Mexico . *trichecus*, *transvorsus*, *capitulatus*, and *æquatus*.
   Species of unknown origin, but closely allied to *H. pacificus* Ckll., with the size smaller; the enclosure of metathorax shorter, with finer striæ, etc. . . . . *citerior*.
8. Species of Mexico . *crocoturus*, *tricnicos*, *jubatus*, *circinatus*, *pharus*, *costalis*, *spinalis*, and *pallicornis*, the last based on a ♂.
   Species of British Columbia and Washington State; ♀ $10\frac{1}{2}$ mm. long, black . . . . *egregius*.
   Species of Colorado; ♂ $7\frac{1}{2}$ mm. long, black, the apical half of the clypeus yellowish . . . . *colatus*.
9. Posterior face of metathorax with a distinct sharp margin . . 10.
   Posterior face of metathorax with the lateral margins at least partly rounded . . . . 22.
11. Females . . . . 12.
    Males . . . . 14.
12. Smaller, length less than 7 mm. (Mexico) . . *respersus* and *laneus*.
    Larger, length $7\frac{1}{2}$ mm. . . . . 13.
    Largest, length $8–8\frac{1}{2}$ mm.; black (South Carolina, New York, Georgia) . . . . *crassus*.[1]
13. Abdominal bands at bases of segments 1 to 3 entire (Colorado) . . . . *granosus*.
    Abdominal bands reduced, segments 2 and 3 having only small grayish spots on each side (Washington State) . . . . . *occultus*.
14. Legs black (Mexico?) . . . . *adelipus*.
    At least the tarsi partly yellow . . . . 15.
15. Labrum black (California; a black species $8\frac{1}{2}$ mm. long) *pullilabris*.
    Labrum yellow or testaceous . . . . 16.
16. Mandibles black, at least basally, never yellow . . . . 17.
    Mandibles more or less spotted with yellow . . . . . 19.
17. Anterior tibia without a yellow stripe; tubercles and tegulæ not spotted with yellow (Colorado) . . . . . . *granosus*.
    Anterior tibia striped with yellow; tubercles and tegulæ with a yellow spot . . . . 18.
18. Larger, length $9–9\frac{1}{2}$ mm., face below the antennæ longer (British Columbia) . . . . *arctous*.
    Smaller, length 7 mm.; face below the antennæ shorter (California) . . . . *nigridens*.
19. Tubercles dark; face short, eyes converging below; basal area of metathorax almost semicircular, entirely occupied by irregular striolæ; length $7–7\frac{1}{2}$ mm. (Colorado) . . . . . *nigricollis*.

[1] *H. crassus* is said to differ from *H. similis* Sm., by its larger size, and the smoky yellow tint of the wings, and from *H. fulgidus* Crawf., by the color of the wings and the less punctured abdomen.

Tubercles, tegulæ, and anterior tibia more or less tinged or marked with yellow . . . . 20.
20. Length 6 mm. or less; anterior tibia spotted with brown; sixth ventral segment of abdomen without an impression (California) . *gularis*.
Length $6\frac{1}{2}$ mm. or more . . . . 21.
21. Species of Mexico . . . . *aratus*.
Species of Colorado; all the tibiæ yellow . . . . *gelidus*.
22. Only the apical border of the abdominal segments pale . . 23.
Abdomen almost entirely reddish; 5 mm. long (Oaxaca, Mexico) . . . . *curtulus*.
23. Species supposed to be Mexican; black, head small . *bivarus*, ♀.
Species of Colorado, Nevada, and Vancouver I.; about 6 mm. long, shining black; face long; mesothorax and scutellum finely, densely punctured; enclosure of metathorax lunate, with fine, irregular, indistinct striæ; wings bronzy-hyaline, nervures yellow: male with labrum dark, and legs brown, without yellow or testaceous markings . . . . *diatretus* ♂, ♀.
24. Not metallic . . . . 25.
At least the head or thorax more or less metallic . . . . 26.
25. Posterior face of metathorax with a sharp border; black, head large: hind spur pale, with three sharp spines (Washington State) *fartus*, ♀.
Posterior face of metathorax with its lateral margins rounded, at least above; black, head small; length, ♀ $6\frac{1}{2}$–7, ♂ 6 mm. (Mexico) *sertus*.
26. Species of South America
beskei (Brazil), *autranellus* (Buenos-Aires), *pisinnus* (Chile).
Species of unknown locality; ♂ 7 mm. long, green . *lanifer*.
Species of Mexico . . . . 27.
27. Less than 7 mm. long . . . . *cubitalis*, *sudus*, and *terginus*.
Over 7 mm. long . . . . *biseptus*, *ectypus*, and *coactilis*.

T. D. A. Cockerell.

Notes on Recent Fish Literature.— Mr. C. Tate Regan, of the British Museum, continues his varied series of fish studies by a number of short papers in the *Annals and Magazine of Natural History*. One of these, "The Phylogeny of the Teleostomi" (May, 1904), must challenge the attention of all palæontologists by its bold theory that the chondrostean ganoids (Palæoniscum, Acipenser, Polyodon, etc.) are the most primitive of teleostomous fishes, and that they have given rise to the crossopterygians and dipnoans as well as to the ostracophores, arthrodires, and teleosts. After separating the still more primitive sharks, Mr. Regan divides the other fishes into five orders, Chondrostei, Crossopterygii, Placodermi, Dipneusti, and Teleostei. The Teleostei have sprung, in his scheme,

from the chondrostean ganoids, through the holostean ganoids (Aspidorhynchus, Lepisosteus, Amia, etc.) which he regards as teleosts. On the other hand, the Crossopterygii, likewise descended from Chondrostei, have given rise to Dipneusti (dipnoans) and also to Placodermi. This latter group includes both Ostracophores and Arthrodires. The Heterostraci are excluded from this group, being regarded as armored sharks.

The fact that palæontology does not bear out this view is dismissed with the statement that these conclusions "are in accordance with the morphological evidence, which is clearly and sufficiently complete, whilst the geological record is and must be from the nature of the case very incomplete."

The close resemblance between the basal structures of the paired and the unpaired fins in the Chinese Paddle-fish (*Psephurus gladius*) is one of the important pieces of evidence in favor of the primitive nature of the Chondrostei, and in favor of the origin of all fins alike from folds of skin.

The conclusions of Mr. Regan are thus summed up:

1. The Chondrostei are the most generalized Teleostomi.

2. The Crossopterygii differ from them in the lobate pectoral fin and in the larger paired gular plates.

3. The placoderms (Coccosteidæ, Asterolepidæ, Cephalaspidæ) are a natural group not related to the Heterostraci, which are Chondropterygii. They may probably be regarded as armored primitive Crossopterygii, this view being most in accordance with the arrangement of the cranial roof bones in Coccosteus, the structure of the ventral fin in Coccosteus, and the structure of the pectoral limb in Asterolepidæ (which structure he regards as a true pectoral fin).

4. The Dipneusti probably originated from more specialized Crossopterygii, *e. g.*, from the neighborhood of the Holoptychidæ.

5. The Teleostei differ in so many respects from the Chondrostei that they should rank as an order in which the Holostei are included.

This view of the case is original and suggestive, but so far as the major premise (No. 1 above) is concerned, most naturalists will find it unconvincing.

Mr. Regan discusses the genus Lichia of Cuvier, dividing it into two genera, Lichia (Amia) and Campogramma Regan (Vadigo). *Lichia glauca* he refers to the genus Trachinotus. The gaff-top-sail Pampano, also called *Trachinotus glaucus*, a name of later date, is deprived of its name by the intrusion into the same genus of an

earlier *glaucus*. To this American species Regan gives the new name of *Trachynotus palometa*. Porthmeus is a synonym of Lichia, while Hypodis Rafinesque, not mentioned by Regan, is a synonym of Trachinotus.

Regan re-describes *Holocentrus osculus* Poey, and describes *Centropomus argenteus*, a new species, allied to *C. ensiferus*, from Barbadoes and Guiana. *C. mexicanus* he regards as identical with *Centropomus parallelus*.

The following new species are also described by Mr. Regan: *Clupea* (*Opisthonema*) *bulleri* from Las Peñas in Jalisco; *Engraulis argentivittatus* from Las Peñas; *Pseudoxiphophorus pauciradiatus* from Orizaba; *Zoogoneticus maculatus* from Rio Santiago;[1] *Characodon geddesi* from Lake Tezcoco, Mexico; *Heros octofasciatus* from British Honduras; *Heros callolepis* from Santo Domingo de Guzman, Mexico; *Pristigaster* (*Opisthopterus*) *effulgens* from Ecuador; *Ophichthys* (*Pisodontophis*) *brevimanus* from Ecuador; *Piabucina astrigata* from Ecuador; *Piabucina pleurotænia* from Venezuela; *Trichomycterus vittatus* from Peru; *Trichomycterus retropinnis* from Colombia; *Trichomycterus meridæ* from Venezuela; *Pimelodus* (*Pimelodella*) *tæniophorus* from Matto Grosso; *Pimelodus* (*Pimelodella*) *griseus* from Ecuador; *Haplochilus peruanus* from Peru; *Belone* (a *Tylosurus*) *fluviatilis* from Ecuador; *Centropomus atridorsalis* from Ecuador; *Corvina* (a *Sciæna*) *crawfordi* from Montevideo; *Acara saparensis* from Ecuador; *Gobius* (*Awaous*) *guentheri* from Ecuador;[2] *Chasmodes maculipinna* from Ecuador; *Chætodon dixoni* from the New Hebrides; *Draconetta acanthopoma* from the deep waters of the North Atlantic.

Draconetta is considered by Mr. Regan, probably correctly, as an ally of Harpagifer. The nominal family of Draconettidæ is therefore not to be separated from the Harpagiferidæ, and is a close ally of the Nototheniidæ.

A considerable collection made at Rio Janeiro by Dr. Gœldi is the subject of an important paper. The following are the chief additions:

Raia cyclophora new species; *Muræna helena* a Mediterranean

[1] *Fundulus labialis* and *F. guatamalensis* are probably not species of Zoogeneticus as has been suggested by Dr. Meek.

[2] *Gobius latus* O'Shaughnessy is not identical with *G. flavus* nor with *G. banana*. *Gobius* or *Awaous banana*, the West Indian species, should not be identified with *Gobius* (*Awaous*) *taiasica*, a Brazilian species which is probably the same as *Awaous latus*.

species now recorded from Brazil; *Atherinichthys sallei* for a new species of Menidia from Mexico; *Serranus flaviventris* should include *S. dispilurus*, *S. subligarius*, and *S. brasilienis.* It is distinct from *S. auriga. Diagramma gœldii* is identical with *Genypterus cavifrons*, for which species Mr. Regan does not accept the older but somewhat doubtful name, *luteus. Mylacrodon gœldii* is a new genus allied to Pomadasis but with some molar-like teeth.

The Old World genera, Gazza and Leiognathus, are referred to the Gerridæ, from which they differ in the small scales and in having the gill membranes narrowly united to the isthmus. Regan gives an analysis of the striped species of true Gerres he regards as tenable, *viz.*, *brevimanus*, *plumieri*, *mexicanus*, *lineatus* (including *brasilianus* and *embryx* of the Atlantic coast), *axillaris*, and *patao. G. brasilianus* is, however, not the same as *G. lineatus.*

Pristedion altipinnis new species; *Oligoplites saliens* (with four dorsal spines) is a valid species, as are also *O. palometa*, *altus*, *saurus*, and *mundus.*

Not knowing the species of Spanish Mackerel, called *Scomberomorus regalis*, Regan identifies it with *S. maculatus.* The fishermen know better. *Scomberomorus immaculatus* from San Domingo is not identical with *S. cavalla.*

Genypterus brasiliensis, new species; *Achirus fonsecensis* is recorded for the first time from the Atlantic and *Lophius piscatorius* for the first time from Brazil.

In 1900, the "*Albatross*" made a short dredging cruise on the coast of Japan, taking 111 species of fishes. Of these, 58 were new to science and have been described by President Jordan and his associates. In a paper in the *Bulletin* of the United States Fish Commission for 1903, figures of all these new species are given, with references, notes, and descriptions of a number of new species. This memoir is by Jordan and Starks. With it is included a monographic review of the Macrouridæ, or Grenadier-fishes of Japan, by Jordan and Gilbert, with figures of most of the numerous species.

The most important faunal work in ichthyology for the year is the account of the Fishes of Panama Bay by Professor Charles H. Gilbert and Mr. Edwin C. Starks, published by the California Academy of Sciences (Mem., Vol. 4), and reprinted by the Hopkins Seaside Laboratory of Stanford University.

This paper contains a very full account of the fishes of Panama,

374 in all, with excellent plates, the work of Mrs. Chloe Lesley Starks, representing most of the new forms. The descriptions are prepared with that minute attention to accuracy characteristic of all of Dr. Gilbert's work. Of the many new species, the majority were included in the appendix to Jordan and Evermann's fishes of North America. Those not so included are the following:

Galeichthys eigenmanni, *Tachysurus evermanni*, *Fistularia corneta*, *Oligoplites refulgens*, *Peprilus snyderi*, *Sagenichthys* (properly *Macrodon*) *mordax*, *Pomacentrus gilli*, *Halichœres macgregori*, *Balistes verres*, *Xesurus hopkinsi*, *Guentheridia*, a new genus of Tetraodontidæ (*formosa*), *Prionotus ruscarius*, *Microgobius miraflorensis*, *Evermannia panamensis*, *Batrachoidea boulengeri*, *Porichthys greenei*, *Hypsoblennius piersoni*. *Lythrulon opalescens* is not distinguishable from *L. flaviguttatum*, and *Menticirrus simus* is identical with *M. nasus*. *Eleotris æquideus* cannot be separated from *E. pictus*, and *Microgobius cyclolepis* is the same as *M. emblematicus*. *Ancyiopsetta sabanensis* is identical with *A. dendritica*, and the genus *Ramularia* is not tenable. *Solea fischeri* and *Solea panamensis* are synonyms of *Achirus fonsecensis*.

The following conclusion as to the relations of the fish faunas on the two sides of the isthmus of Panama is of special interest. "The ichthyological evidence is overwhelmingly in favor of the existence of a former open communication between the two oceans, which must have become closed at a period sufficiently remote from the present to have permitted the specific differentiation of a very large majority of the forms involved. That this differentiation progressed at widely varying rates in different instances becomes at once apparent. A small minority of the species remains wholly unchanged, so far as we have been able to determine that point. A large number have become distinguished from their representatives of the opposite coast by minute (but not 'trivial') differences, which are wholly constant. From such 'representative forms,' we pass by imperceptible gradation to species much more widely separated, whose immediate relation in the past we cannot confidently affirm. Of identical species, occurring in both oceans, our Panama list contains 43.

"The total number of identical species which we recognize in the two faunas now separated by the Isthmus is therefore 54, as compared with the 71 enumerated by Jordan (1885). It is obvious, however, that the striking resemblances between the two faunas are shown as well by slightly divergent as by identical species, and the evidence in favor of interoceanic connection is not weakened by an increase in

one list at the expense of the other. All evidence concurs in fixing the date of that connection at some time prior to the Pleistocene, probably in the early Miocene. When geological data shall be adequate definitely to determine that date, it will give us the best known measure of the rate of evolution in fishes.

Of the 82 families of fishes represented at Panama, all but 3 (Cerdalidæ, Cirrhitidæ and Nematistiidæ) occur also on the Atlantic side of Central America; while of the 218 genera of our Panama list, no fewer than 170 are common to both oceans. The well-developed families Centropomidæ and Dactyloscopidæ are peculiar to the tropical faunas now separated by the Isthmus of Panama."

In the *Journal* of the Academy of Natural Sciences at Philadelphia (Vol. 12), Mr. Henry W. Fowler has a valuable report on the fishes collected in Sumatra by Harrison and Heller; 248 species are embraced in this collection. This includes a number of new species. This paper contains notes on the little known forms, with excellent plates of many of them. The paper will be of great value in the study of the East Indian fauna. Several new subgenera are proposed. Deveximentum is a new genus allied to Leiognathus, based on *L. insidiator*; the same species is the type of the earlier name Equula.

In the *Proceedings* of the California Academy of Sciences, Vol. 3, series 3, the late Cloudsley Rutter records a few fishes from the Gulf of California. He unites the genus Villarius with Ictalurus and describes a new Eleotrid Goby under the name of *Pycnomma semisquamatum*. The genus is certainly close to the imperfectly known genus Gymneleotris. A new description of *Emblemaria oculocirris* is given.

In the same *Proceedings* Dr. Charles H. Gilbert has notes and descriptions of fishes of the Pacific. *Netuma mazatlana*, new species, from Mazatlan; *Nemichthys avocetta*, which is properly the same as *N. scolopaceus*;[1] *Schedophilus heathi*, new species, from Monterey; *Xeneretmus infraspinatus*, new species, from Cape Flattery. *Clevelandia rosæ* is identical with *Clevelandia ios*; *Rathbunella alleni*, new species, from Monterey; *Auchenopterus mexicanus*, new species, from La Paz.

[1] The supposed character of the dorsal rays in Nemichthys distinguishing it from other eels is fallacious, being produced by the drying of the specimen.

In the *Report* of the Illinois Fish Commission for 1902, Mr. Thomas Large gives a useful list of the fishes of Illinois, with analytical keys and notes on the different species.

In the *Proceedings* of the U. S. National Museum (Vol. 27) Jordan and Snyder describe new species of fishes from Hawaii as follows: *Brachysomophis henshawi*, *Ariomma lurida*, *Lactoria schlemmeri*, *Antennarius laysanius*, and *Apogon evermanni*. A number of other species are added to the fauna of the islands. Ariomma is a new genus, apparently allied to Apogon.

In the *Proceedings* of the Biological Society of Washington (Vol. 17) Dr. H. M. Smith describes a small eel found in the deep waters south of Nomans Land. It is entirely black and with the eyes wholly hidden. Otherwise it is quite similar to the common eel. Dr. Smith calls it *Anguilla cæca*.

In the *Proceedings* of the Scientific Society of Christiania for 1904, Dr. Collett describes four new species of deep-sea fishes from the Faroë Islands. These are *Etmopterus princeps*, *Pristiurus murinus*, *Chimæra mirabilis*, and *Halargyreus affinis*. The Chimæra is made the type of a new subgenus called Bathyalopex, having the anal united with the caudal. The Japanese species *mitsukurii* would belong to this group, which is, however, scarcely entitled to distinctive rank.

In the *Bulletin* of the Museum of Comparative Zoölogy at Harvard College (Vol. 46, No. 1) Dr. Eastman gives a very interesting account of the history of the fish collections from Monte Bolca in Tuscany. A fine collection of these fishes is now in the Museum of Comparative Zoölogy. Dr. Eastman gives the synonymy of the principal species in this collection, with descriptions and figures of the most important species. The new generic name Histionotophorus is proposed for a Lophioid form and a new species of Pygæus, *P. agassizi*, is described and figured. The species called *Symphodus szajnochæ* doubtless represents a new genus of Labridæ, and the so-called *Caranx primævus* should also represent a new genus even more Trachurus-like than Trachurus itself.

In the *American Journal of Science* (Vol. 18, No. 104), Dr. Eastman discusses the appendages of Asterolepis. He regards these paddles as not homologous with the pectoral fins of the true fishes, his view being opposed to that recently put forth by Mr. Regan.

In the *Journal* of the College of Science of Tokyo (Vol. 19) Dr. Bashford Dean gives an elaborate account of the anatomy of the long-snouted Chimæra of Japan, *Rhinochimæra pacifica*.

In the *Journal* of the College of Science at Tokyo, Dr. Bashford Dean discusses the hag-fishes, or Myxinoids, of Japan, describing a new genus, *Paramyxine atami*, and a new species, *Homea okinoseana*. He also adds notes on *Homea burgeri* and *Myxine garmani*, with an analysis of the species of the genus, which he calls Homea, but which must stand under the less satisfactory but earlier name of Eptatretus. In the same *Journal* Dr. Dean has notes on the Chimæras of Japan, giving a full account with excellent plates of *Chimæra mitsukurii* and *C. phantasma*. The distinction between these two species was recognized almost simultaneously by Jordan and Snyder, who adopted the name "*mitsukurii*" proposed by Dr. Dean in correspondence.

Dr. Léon Vaillant in the *Comptes Rendus* for 1904 gives an interesting account of the Japanese goblin shark, *Mitsukurina owstoni*, of which a specimen about seven feet long has been received by the Museum at Paris. Dr. Vaillant puts the species in the family of Lamnidæ with Odontaspis and other related forms.

In the *Bulletin* of the Museum at Paris for 1903, Dr. Vaillant gives an account of the hatching of eggs in the branchial cavity in the species of Apogon-like fish, called *Cheilodipterus affinis*, at Martinique.

In the same *Bulletin*, Dr. Vaillant and Dr. Pellegrin give new descriptions of the species of Tetragonopterus, very briefly and unrecognizably mentioned in 1868 by Dr. M. F. Bocourt in the *Bulletin* of the Société Zoölogique de France. Dr. Pellegrin also gives an account of fishes collected on the coast of Chile.

In the *Records* of the Australian Museum (Vol. 5, No. 4), Mr. Edgar R. Waite gives a valuable account of rare fishes lately taken on the coast of eastern Australia. He shows that the genus Goodella is the larval form of Trachinocephalus. The identity of the Japanese genus Iso with the Australian Tropidostethus is also indicated; but Mr. Waite overlooks the fact that the latter name is preoccupied, and the genus may still remain Iso.

In the *Zoologischer Anzeiger* (Vol. 27, No. 22), Dr. L. S. Berg describes a new genus of sturgeons which he calls Huso, the type being *Acipenser huso*. This differs from the other sturgeons in having the gill membranes united, forming a free fold across the isthmus. The snout is soft and flexible and the very large mouth includes the whole under surface of the snout. The barbels are compressed. This definition is a new one, but the generic name Huso was used by Brandt and Ratzeburg in 1883 for a subgenus including the same type.

Under the title of "Pescas do Annie," Dr. Alipio de Miranda Ribeiro gives an account of fishes taken by the Steamer "*Annie*" off the coast of Brazil with the "otter trawl." Fifty-nine species were obtained. These are illustrated by means of photographs. Among the new species are *Fistularia rubra*, *Anthias duplicidentatus*, *Liocsacus intermedius*, *Pontinus corallinus*, *Peristedion roseum*, *Pseudopercis numida*, *Hypsicometes heterurus*, *Lepophidium fluminense*, *Urophycis mystaceus*, *U. latus*, *Paralichthys triocellatus*, and *Gymnachirus zebrinus*.

In *Sports Afield* for August, 1904, Dr. Barton W. Evermann gives valuable suggestions as to how to study a lake. This has particular reference to training children and young students to learn how to weigh evidence. Dr. Evermann calls attention to the fact that most of the so-called "bottomless" lakes are from 40 to 60 feet deep.

In the *Bulletin* of the U. S. Fish Commission for 1904 Dr. Jordan gives an account of fishes collected by Dr. Joseph C. Thompson on the Tortugas, with the descriptions of several species, four of them new, *viz.*:— *Ctenogobius tortugæ*, *Gnatholepis thompsoni*, *Elacatinus oceanops*, and *Ericteis kalisheræ*. A new genus, Acteis, is proposed for the small blenny called *Malacoctenus moorei*.

Under the title of "The Fresh-water Fishes of Mexico north of the Isthmus of Tehuantepec," the Field Columbian Museum publishes a most valuable faunal monograph by Dr. Seth Eugene Meek. It represents the results of two expeditions to Mexico, together with the examination of all previous papers on the fish fauna of that region. Two hundred and twenty-seven species are described, 28 of them being new, with three new genera. Excellent plates of these species and many others are given, with a map of Mexico, and

a very illuminating discussion of the faunal regions into which Mexico is divided. .

The new genera are Cynodonichthys, allied to Fundulus, but with large canines, Paragambusia, and Thorichthys, the latter related to Cichlasoma. Dr. Meek recognizes four distinct fish faunas in Mexico. One of these in the northeast is composed largely of migrants from the north, as Carpiodes, Ictalurus, Lepisosteus. Another is made up of migrants from the south, as Rhamdia, Cichlasoma, etc. The third region includes the valley of the Rio Grande de Santiago, including the now isolated lakes about the city of Mexico. This includes most of the characteristic Mexican types as Chirostoma, Goodea, Aztecula, Evarra, etc. Very many species in this region are viviparous. The genus Chirostoma stands out as almost the only case among fishes where numerous closely related species inhabit exactly the same waters. In the large lake of Chapala, there are eight closely allied representatives of this type, all taken in the same nets, and all alike known in the markets as the "Pescado blanco," noted for its delicate flavor. These species are *Chirostoma chapalæ*, *grandocule*, *promelas*, *sphyræna*, *lucius*, *lermæ*, *ocotlanæ*, and *estor*. In several other lakes, other species occur in similar assemblages. But one species of Chirostoma is known outside the Lerma-Santiago fauna. In almost every other case among fishes, where two closely related species occur, they are not in the same waters, but in neighboring waters. This indicates that almost all species of fishes have originated through geographical isolation. Possibly the forms of Chirostoma may have come into existence as mutations or saltations. In no other case in ichthyology is this theory equally plausible. The fourth faunal basin of Mexico includes the large river Balsas, flowing southward, and containing but few kinds of fishes. The most notable is a very large cat-fish peculiar to this basin, constituting the genus Istlarius.

In the *Bulletin* of the Illinois State Laboratory of Natural History (March, 1904), Mr. R. E. Richardson gives a monographic review of the sun-fishes (Lepomis and Eupomotis) found in Illinois. He places *euryorus* in the genus Lepomis, and recognizes two species (*gibbosus* and *heros*) under Eupomotis. Apomotis Mr. Richardson unites with Lepomis.

Otaki and Fujita have published two more folios of their "Fishes of Japan," (Tokyo, 1904,) with Japanese text, and large colored plates well executed, but of a size inconvenient for binding.

In the *Report* of the Government Biologist of the Cape of Good Hope for 1903, Dr. J. D. F. Gilchrist describes seventeen new species of fishes from that region. One new genus, Cyttosoma, allied to Cyttus, is also recorded.

In Vol. II of the *Results of the Danish Ingolf Expedition*, Dr. Adolf Severin Jensen gives an elaborate account of the Lycodinæ of North Europe and Greenland, with a series of excellent plates. The genus Lycodalepis is united by Jensen with Lycodes. The species generally receive better definitions than have been given by any previous author.

Dr. Gill discusses in the *Proceedings* of the United States National Museum for 1904 the relations of the family of Ammodytidæ. In view of the discovery of the Ammodytoid genus Embolichthys, with jugular ventrals, these fins being wanting in all previously known species, the group belongs among the jugular fishes. Dr. Gill finds no relative nearer than the Hemerocoetidæ.

In the *Biological Bulletin* for October, 1904, Mr. Edwin C. Starks discusses the osteology of the fishes of the order or suborder Haplomi. He finds it a heterogeneous group, including probably varying lines of descent, having the bond of union of abdominal ventral fins, no fin spines, and the loss of the mesocoracoid and orbitosphenoid characteristic of more primitive fishes.

In the *Revista Chilena de Historia Natural*, for 1904, Dr. Carlos E. Porter describes some new fishes from the deep seas of Chile.

In the *Transactions* of the Zoölogical Society of London, for 1904, Mr. C. Tate Regan gives a voluminous and important monograph of the mailed cat-fishes of the South American fauna known as Loricariidæ.

Dr. Joseph Schmitt publishes in Paris a valuable *Monographie de l'Ile Anticosti*, with a list of its animals, about 25 common fishes being included.

Jordan and Snyder describe in the *Proceedings* of the U. S. National Museum for 1904, *Apogon evermanni*, a new fish from Hawaii.

D. S. J.

BOTANY.

Silviculture.[1]—Silviculturists and others interested in forest management will welcome the second part of Professor Mouillefert's comprehensive treatise which is now out. The first part having considered in much detail from the forester's point of view the most important tree species, this second part deals especially with the management and exploitation of trees in assemblages or forests. After defining precisely the terms used, the author considers most comprehensively the principal methods of developing and harvesting the two forms of wood, high forest and coppice, and the application of these methods to the principal species of trees; gives advice as to what to seek in any given case, and describes the nature and amount of the product to be obtained, giving volume curves, directions for developing a forest working plan, calculations of annual revenue, and so on. Special chapters deal with the cultivation of osiers for the draining of soils and with the culture of truffles. The chief modes of cropping and marketing forest products are also taken up.

While special parts, such as rules for forest management and the tables of annual returns, are based upon conditions different from our own (it being possible by reason of the centuries of forestry practice in France to lay down rules of practice and estimate yields much more definitely than with us) nevertheless the general aspects of the subject, the principles of the science and art of silviculture are set forth so clearly and simply that the book is bound to be of general interest to foresters and students of forestry in this country. It will be particularly helpful in making clear to many certain sides of the subject, such as the mathematics of forest measurements, which, as they are often set forth in works on forestry, are not likely to be easily understood.

C. S. S.

Notes. — Loeb's St. Louis address on the recent development of biology is printed in *Science* of December 9th.

An important addition to the rather abundant recent literature of apogamy is made by Strasburger, in a study of Alchemilla published in the opening number of Vol. 41 of the *Jahrbücher für wissenschaftliche Botanik*.

[1] Mouillefert, P. *Traité de Sylviculture* — Part 2 — *Exploitation et Aménagement des Bois*. Paris, Alcan. 1904. 12mo, 476 pp., 10 pls. 97 figs.

An account of the "blaze-currents" of vegetable tissues, by Waller, forms part of Vol. 37, No. 257, of the *Journal* of the Linnean Society, Botany.

A paper on the absorption of electro-magnetic waves by living vegetable organisms, by Squier, has been reprinted from General MacArthur's *Report* to the War Department on the Military Manœuvres in the Pacific Division, 1904.

A considerable discussion of the use of copper for the treatment of polluted drinking water is contained in the *American Journal of Pharmacy* for December.

The "summer-fall" of the leaves of Canary Island plants forms the subject of a note by Vahl in Heft 2 of the *Botanisk Tidsskrift* for 1904.

An interesting study of sandal seedlings is published by Barber in *The Indian Forester* for December.

Papers on myrmecophilous plants by Morteo and Villani are contained in Vol. 18, Fascicle 10–12 of *Malpighia.*

Methods of surveying vegetation on a large scale are discussed with illustrative diagrams, by Oliver and Tansley in *The New Phytologist* of December 20.

Certain traumatic floral anomalies, and their heredity, are discussed by Blaringhem in the *Bulletin* of the Muséum d'Histoire Naturelle of Paris, 1904, No. 6.

A paper on the structure of the starch grain, by Denniston, has been separately issued from Vol. 14 of the *Transactions* of the Wisconsin Academy of Sciences.

An anatomical study of *Anemiopsis californica* is published by Holm in *The American Journal of Science* for January.

A paper by Drabble on the anatomy of the roots of palms forms Vol. 6, Part 10, of the current botanical series of *Transactions* of the Linnean Society of London.

An interesting presentation of some of Burbank's experiments is given by Jordan in *Popular Science Monthly* for January.

A progress report on the strength of structural timber, by Hatt, forms *Circular No. 32* of the Bureau of Forestry, U. S. Department of Agriculture.

A further study of the "popping" of Indian corn, by Professor Storer, is contained in Vol. 3, Part 4 of the *Bulletin* of the Bussey Institution.

Heckel publishes a paper on *Solanum commersoni* and its variations as bearing on the origin of the cultivated potato in the *Revue Horticole* of Marseilles for November.

The banana in Hawaii forms the subject of *Bulletin No. 7* of the Hawaii Agricultural Experiment Station, by Higgins.

Bulletin No. 88 of the Bureau of Chemistry, U. S. Department of Agriculture, is devoted to the chemical composition of apples and cider.

A paper on California olive oil, by Shaw, forms *Bulletin No. 158* of the Agricultural Experiment Station of that State.

Some nature-photograms of cross-sections of wood are published by Russell in the *Gardeners' Chronicle* of November 26.

An ecological study of Brush Lake, by Schaffner, Jennings, and Tyler, forms Vol. 4, Part 4, of the *Proceedings* of the Ohio State Academy of Science.

A "Pugillus Cryptogamarum Canadensium," by Cufino, is published in *Malpighia*, Vol. 18, Fascicle 10–12.

Under the title "Bouquet de Fleurs de Chine," Léveillé publishes a number of new Chinese species in Vol. 39, Fascicle 4, of the *Bulletin* de la Société d'Agriculture, Sciences et Arts de la Sarthe.

A second paper on new or noteworthy Philippine plants, by Merrill, forms [*Bulletin*] *No. 17* of the Bureau of Government Laboratories of the islands, dated October 1, 1904.

Part 10 of Koorders and Valeton's "Additamenta ad Cognitionem Floræ arboreæ Javanicæ" forms No. 68 of the *Mededeelingen uit 's Lands Plantentuin.*

The flora of western Australia is receiving important treatment by Diels and Pritzel in current numbers of Engler's *Botanische Jahrbücher.*

Vol. 4 of the "Flora of Tropical Africa," edited by Sir William T. Thiselton-Dyer, has recently been completed.

Several additional species of Eschscholtzia are described by Fedde in No. 35 of the *Notizblatt* of the Berlin Garden.

A number of new species of cacti are described from the notes of the late Dr. Weber, by Gosselin, in No. 6 of the *Bulletin* of the Muséum d'Histoire Naturelle of Paris for 1904.

An attractive book, "Abbildungen der in Deutschland und den angrenzenden Gebieten vorkommenden Grundformen der Orchideen-Arten," by Müller, with descriptive text by Kränzlin, has been issued by R. Friedländer & Sohn, of Berlin.

Some interesting test-tube cultures of orchids are detailed by Bernard in the *Revue Générale de Botanique* of Nov. 15.

A revision of Tradescantia, as known from Texas, is published by Bush in Vol. 14, No. 7, of the *Transactions* of the Academy of Science of St. Louis.

The prothallium of *Ophioglossum vulgatum* is described by Bruckmann in the *Botanische Zeitung* of December 15.

Regnellidium diphyllum, the type of a new genus of Marsiliaceæ, from Brazil, is described and figured by Lindman in Vol. 3 of *Arkiv för Botanik.*

An important paper on Cyanophyceæ, by Zacharias, is separately printed from Vol. 21 of the *Jahrbuch der Hamburgischen wissenschaftlichen Anstalten.*

The first part of a historical review of the origin of species by mutation is contributed by Harris to *The Monist* of October.

An important paper by Goebel on cleistogamous flowers and the adaptation theories is begun in the *Biologisches Centralblatt* of November.

The summer activity of some spring flowers is discussed by Dr. Keller in Part 2 of the current volume of *Proceedings* of the Academy of Natural Sciences of Philadelphia.

A paper on the origin and nature of color in plants, by Kraemer, is contained in the *Proceedings* of the American Philosophical Society, No. 177.

Country Life in America for December contains striking pictures of *Anemone patens nuttalliana* blooming in the snow.

A lecture by Haberlandt on the sense organs of plants is being published in current numbers of the *Naturwissenschaftliche Rundschau.*

A treatise on the transpiration of plants, by Burgerstein, has recently been issued from the press of Gustav Fischer of Jena.

Bower's St. Louis address, dealing with the relation of the axis to the leaf in vascular plants, is printed in *Science* of October 21.

Coulter's St. Louis address on the development of morphological conceptions is printed in *Science* of November 11th.

A paper on cytological technique, by Osterhaut, forms Vol. 2, No. 11 of the botanical series of *University of California Publications.*

The comparative age of the different floristic elements of eastern North America is discussed by Harshberger in a separate from the August *Proceedings* of the Academy of Natural Sciences of Philadelphia.

Westgate gives an account of the reclamation of the Cape Cod sand dunes in *Bulletin No. 65* of the Bureau of Plant Industry of the U. S. Department of Agriculture.

Certain plants of the north temperate zone are contrasted with their representatives in the high mountains of tropical Africa by Engler in the *Annals of Botany* for October.

The second section of Volume 4 of the "Flora Capensis," covering Hydrophyllaceæ to Pedalineæ, has recently been completed, with index, under the editorship of the Director of the Kew Gardens.

An interesting paper on the forest flora of the Jubbulpore district of India is published by Hole in *The Indian Forester* of November.

The botanical zones of the Madeiras are discussed by Menezes in Vol. 8 of the *Annaes de Sciencias Naturaes* of Oporto.

An account of *Liquidambar styraciflua* is contributed to Nos. 8 and 9 of the current volume of *Anales del Museo Nacional de México*, by Alcocer.

De Vries' *Trifolium pratense quinquefolium* is discussed by Tammes in the *Botanische Zeitung*, Abt. 1, of November 15.

An account of the group of peaches known as honey-peaches is given by Reimer in *Bulletin No. 73* of the Florida Agricultural Experiment Station.

An illustrated monograph of the willows of France, with classification of the other European species, by A. and E. G. Camus, has been published from the office of the *Journal de Botanique*, of Paris.

Urbina gives an account of *Pedilanthus aphyllus* in the *Boletín del Museo Nacional de México* of March last.

In the *Gardeners' Chronicle* of Nov. 5 is given, by Müller, the first partial description of some of Sprenger's hybrid Yuccas.

An account of the tight-chaffed wheats, "emmer" and "spelt," by Saunders, forms *Bulletin No. 45* of the Central Experimental Farm, of Ottawa, Canada.

A neatly illustrated handbook of "New England Ferns and their Common Allies," by Helen Eastman, has been issued from The Riverside Press of Cambridge.

315 Pteridophytes, of which a number are new, are noted for Isthmian America by Hieronymus in Engler's *Botanische Jahrbücher* of October 25.

A monograph of North American Ustilagineæ, by Clinton, forming No. 57 of the "Contributions from the Cryptogamic Laboratory of Harvard University," is published as Vol. 31, No. 9, of the *Proceedings* of the Boston Society of Natural History.

Arsenic in papers and fabrics, and the so-called arseno-molds belonging to the genera Aspergillus, Penicillium, and Mucor, are discussed by Haywood and Warren in *Bulletin No. 86* of the Bureau of Chemistry, U. S. Department of Agriculture.

Sydow's "Monographia Uredinearum," in fascicle 5 reaches the end of Puccinia, of which 1231 species are recognized. The contents of the volume are rendered accessible by good indexes.

A paper on Mexican Uredineæ, by Holway, is contained in *Annales Mycologici* for September.

Colletotrichum glœosporioides, and its attacks on the pomelo, form the subject of *Bulletin No. 74* of the Florida Agricultural Experimental Station, by Hume.

Papers on Middleton Fungi — by Gates, and Fungi of Nova Scotia, a provisional list — by MacKay, have been separately issued from the *Proceedings and Transactions* of the Novia Scotian Institute of Science, Vol. 11.

Petri discusses the diagnostic value of the capillitium of Tylostoma in *Annales Mycologici* for September.

A third edition of Frost's "Laboratory Guide in Elementary

Bacteriology" has been issued from the Macmillan press, and gives a most serviceable foundation for a year's work.

An interesting article on invisible micro-organisms, by Dorset, is reprinted from the *Twentieth Annual Report* of the Bureau of Animal Industry, U. S. Department of Agriculture.

Volume 1 of Ward's "Trees: a Handbook of Forest Botany for the Woodlands and the Laboratory" (Cambridge, the University Press, 1904) deals with buds and twigs, and constitutes one of the best of the winter manuals yet published. In the second part of the volume, keys, figures, and descriptions facilitate the determination of British species.

An annotated account of trees and shrubs tested in Manitoba and the Northwest Territories, by Saunders, forms *Bulletin No. 47* of the Central Experimental Farm, at Ottawa, Canada.

In *Nature* of November 24, Mr. H. Charlton Bastian has again taken up the question of heterogenesis.

A contribution to the study of fermentation, by Twight and Ash forms *Bulletin No. 159* of the Agricultural Experiment Station of California.

An elaborate monograph of Hungarian Gasteromycetes, by Hollós, has been issued in German translation from the Weigel Press of Leipzig.

A characteristic colored plate of *Amanita muscaria* is given in *The American Botanist* of October.

A good "fairy-ring," apparently of *Agaricus arvensis*, is figured in *The American Inventor* of January 1, 1905.

Bulletin No. 75 of the Florida Agricultural Experiment Station is devoted to a discussion of potato diseases, by Hume.

A new catalogue of the plants cultivated in the botanical garden at Buitenzorg, by Hochreutiner, is begun in *Bulletin de l'Institut Botanique de Buitenzorg*, No. 19.

An account of the cultivation of *Papaver somniferum*, and the production of opium, in the United States is given by Richtmann in the *Pharmaceutical Review* of November.

A study of the chemical composition of some tropical fruits and their products, by Chace, Tolman, and Munson, forms *Bulletin No. 87* of the Bureau of Chemistry, U. S. Department of Agriculture.

A popular account of Christmas fruits and their sources is published by McFarland in *Country Life in America* for December.

Southern evergreens and their commercial utilization are discussed by Caldwell in *Country Life in America* for December.

Dr. Sherman's bulletin on Gutta Percha and Rubber of the Philippine Islands is being reprinted in *The Far Eastern Review*, of Manila, beginning with the issue of September.

According to No. 5 of the current volume of the *Bulletin du Jardin Impérial Botanique de St. Pétersbourg*, the living collections of plants at that institution in 1903 numbered 34,887 species and varieties, of which 27,516 required the shelter of plant houses.

An account of Bauhin's herbarium, with determinations by A. P. de Candolle, is published by Casimir de Candolle in Vol. 4, No. 3, of the *Bulletin de l'Herbier Boissier*.

M. Correvon, of Geneva, has recently issued an account of the first Congress of Alpine Gardens, held at the Rochers de Naye in August.

The Journals. — *Botanical Gazette*, November: — Jeffrey, "A Fossil Sequoia from the Sierra Nevada"; Shull, "Place-Constants for *Aster prenanthoides*"; Robinson, "A New Sheep-poison from Mexico"; Nelson, "Some Western Species of Agropyron"; MacMillan, "Note on some British Columbian Dwarf Trees"; Jeffrey and Chamberlain, "Celloidin Mechanique"; and Life, "An Abnormal Ambrosia."

The Bryologist, November: — Fink, "Further Notes on Cladonias — IV"; Grout, "Hepatics with Hand Lens."

Bulletin of the Torrey Botanical Club, October: — Bessey, "The Chimney-shaped Stomata of *Holacantha Emoryi*"; Kellicott, "The Daily Periodicity of Cell-division and of Elongation in the Root of Allium"; Emerson, "Relationship of Macrophoma and Diplodia"; Rydberg, "Studies on the Rocky Mountain Flora — XII."

Bulletin of the Torrey Botanical Club, November: — Cushman, "Desmids from Newfoundland"; Horne, "An Anomalous Structure on the Leaf of a Bean Seedling"; House, "The Nomenclature of *Calonyction bona-nox*"; Murrill, "The Polyporaceæ of North America — IX"; Britton, "On *Pisonia obtusata* and its Allies."

Journal of the New York Botanical Garden, November: — Britton, "Report on Exploration of the Bahamas."

Vol. 1 of the *Memoirs* of the Horticultural Society of New York, issued late in 1904, is devoted to the important Proceedings of the International Conference on Plant Breeding and Hybridization held in New York City in October, 1902.

Part 3 of the third series of *Minnesota Botanical Studies* contains the following articles: — Lyon, "The Embryogeny of Ginkgo"; Leavitt, "Observations on *Callymenia phyllophora*"; Warner, "Observations on *Endocladia muricata*"; Mueller, "Observations on *Laminaria bullata*"; Howe, "Minnesota Helvellineæ"; Polley, "Observations on *Physalacria inflata*"; and Freeman, "Symbiosis in the genus Solium."

The Ohio Naturalist, November: — Kellerman and Gleason, "Notes on the Ohio Ferns"; Schaffner, "Leaf Expansion of Trees and Shrubs in 1904"; Gleason, "A New Sunflower from Illinois"; Schaffner, "Twigs of the Common Hackberry," and "Six Mutating Plants."

The Plant World, October: — Safford, "Extracts from the Note-Book of a Naturalist on the Island of Guam — XXIII"; Barrus, "Pussy Willows"; Barrett, "Tanier, the Oldest Crop"; Atwell, "Propagation by Petiole Buds"; Schneck, "Hybridization in the Honey Locust."

Rhodora, October: — Fernald, "The American Representatives of *Pyrola rotundifolia*"; Hoffmann, "Notes on the Flora of Berkshire County, Mass."; Knowlton, "Notes on the Flora of Day Mountain, Franklin Co., Me."; G. E. D., "The Death of William Wendte"; Waters, "*Asplenium ebeneum proliferum*"; Day, "*Juncus effusus compactus* in N. H."; Chamberlain, "*Plantago elongata* in Mass."

Torreya, October: — Underwood, "The Early Writers on Ferns and their Collections — III"; Murrill, "A New Species of Polyporus from Tennessee"; Britton, "The Florida Royal Palm"; Berry, "Otto Kuntze on Sequoia."

Torreya, November: — Harper, "Two Hitherto Confused Species of Ludwigia"; Murrill, "A Key to the Perennial Polyporaceæ of Temperate North America"; Gleason, "Additional Notes on Southern Illinois Plants"; Cockerell, "*Hymenoxys insignis*"; Britton, "*Rhynchospora Pringlei*"; Shafer, "Notes on Cuban Plants"; Grant, "A Peculiar Pea Seedling"; Millspaugh, "A New Bahaman Euphorbia"; E. G. Britton, "The Effect of Illuminating Gas on Trees and

Shrubs"; Greene, "A Name explained [Xolisma or Cholisma]"; Howe, Exogenous Origin of Antheridia in Anthoceros."

Vol. 2, No. 3, of *Contributions from the Botanical Laboratory of the University of Pennsylvania* contains the following articles: — Phillips, "A Comparative Study of the Cytology and Movements of the Cyanophyceæ"; Watson, "Structure and Relation of the Plastid"; Harshberger, "The Relation of Ice Storms to Trees"; Conrad, "Phyllody in Nelumbo"; Cooke and Schively, "Observations on the Structure and Development of *Epiphegus virginiana*"; Boewig, "Histology and Development of *Cassytha filiformis*"; Farr, "Notes on some Interesting British Columbian Plants"; Macfarlane, "The History, Structure and Distribution of *Sarracenia Catesbæi*"; and an announcement of three phanerogamic monographs shortly to be published.

Vol. 2, Part 2, of the *Annals of the Royal Botanic Gardens, Peredeniya* contains a second part, well illustrated, of Wright's "The Genus Diospyros in Ceylon," a paper by Lock "On the Growth of Giant Bamboos," one by Svedelius "On the Life-History of *Enalus acoroides*," and the first of "Studies in Plant Breeding in the Tropics," by Lock.

Botanical Gazette, December: — Copeland, "The Variation of some California Plants"; Newcombe, "Klinostats and Centrifuges for Physiological Research"; Cooley, "Ecological Notes on the Trees of the Botanical Garden at Naples"; Bergen, "Relative Transpiration of Old and New Leaves of the Myrtus Type"; Coulter and Chrysler, "Regeneration in Zamia"; and Parish, "New or Unreported Plants from Southern California."

The Bryologist, January: — Smith, "William Starling Sullivant, with Portrait"; Grout, "Spore Distribution in Buxbaumia"; E. G. Britton, "Notes on Nomenclature.— IV, The Genus Neckera."

The Fern Bulletin, October: — Fitzpatrick, "The Fern Flora of Montana"; Maxon, "Notes on American Ferns — VII"; Dukes, "Fall Fruiting of Osmunda"; Foster, "The Broad Wood Fern in Washington"; Dukes, "Babyhood of Ferns"; Woolson, "*Nephrodium pittsfordensis*"; Fitzpatrick, "Notes on the Ferns of Washington"; Cocks, "Notes from Louisiana"; Clute, "The Jamaica Walking Fern"; Eaton, "*Pellæa ornithopus*"; Hahne, "Forking Ferns"; Phelps, "New Stations for two rare Connecticut Ferns"; Schneck, "*Asplenium Ruta-muraria* on the Towers of Milan Cathedral"; and Clute, "*Adiantum Capillus-Veneris* in Pennsylvania."

The Plant World, November: — Safford, "Extracts from the Note-Book of a Naturalist on the Island of Guam — XXIV"; W. W. Bailey, "River Botanizing"; Wetzstein, "The White Prickly Poppy in Northwestern Ohio."

Rhodora, November: — Brainerd, "Hybridism in the Genus Viola"; Blanchard, "A New Species of Blackberry"; House, "A New Violet from New England"; Clark, "*Dalibarda repens* near Boston"; Ward, "*Mimulus moschatus* in Mass."; and Holt, "Subularia at East Andover, N. H."

Torreya, December: — Shafer, "The American Sennas"; Richards, "A Case of Irregular Secondary Thickening"; Sumstine, "The Boletaceæ of Pennsylvania"; Berry, "Recent Contributions to our Knowledge of Paleozoic Seed-Plants"; Wilson, "Some Introduced Plants in Cuba."

(*No. 457 was issued February 20, 1905*).

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THE ANATOMICAL CHANGES IN THE STRUCTURE OF THE VASCULAR CYLINDER INCIDENT TO THE HYBRIDIZATION OF CATALPA.

D. P. PENHALLOW.

In 1889 Prof. C. S. Sargent published an account of an interesting and newly observed case of hybridization between two species of Catalpa which he designated as Catalpa × J. C. Teas in reference to the origin of the tree in the nursery of Mr. Teas at Carthage, Missouri.[1] The account referred to states that *Catalpa kæmpferi* was planted in 1864 in a nursery containing *C. speciosa* and *C. bignonioides*. Eventually the first species produced a single pod of seeds which were wholly unlike anything hitherto known. When these seeds were planted, they produced a tree almost intermediate in character between *C. kæmpferi* and one of the American species. Mr. Teas was of the opinion that the cross was with *C. speciosa*, while Prof. Sargent considered *C. bignonioides* as the other parent, basing his conclusion upon the fact that *C. speciosa* flowers two to three weeks earlier than *C. kæmpferi*, while the flowers of *C. big-*

[1] *Garden and Forest*, vol. 2, 1889, p. 303.

nonioides are contemporaneous with those of the Japanese species. No other evidence has been forthcoming since then, so far as I am aware, and the real American parentage of a most noteworthy addition to the ornamental trees of this country still remains in doubt. Within the last twelve years, opportunities have been presented to inquire into the evidence which might be secured from an anatomical point of view, and to determine

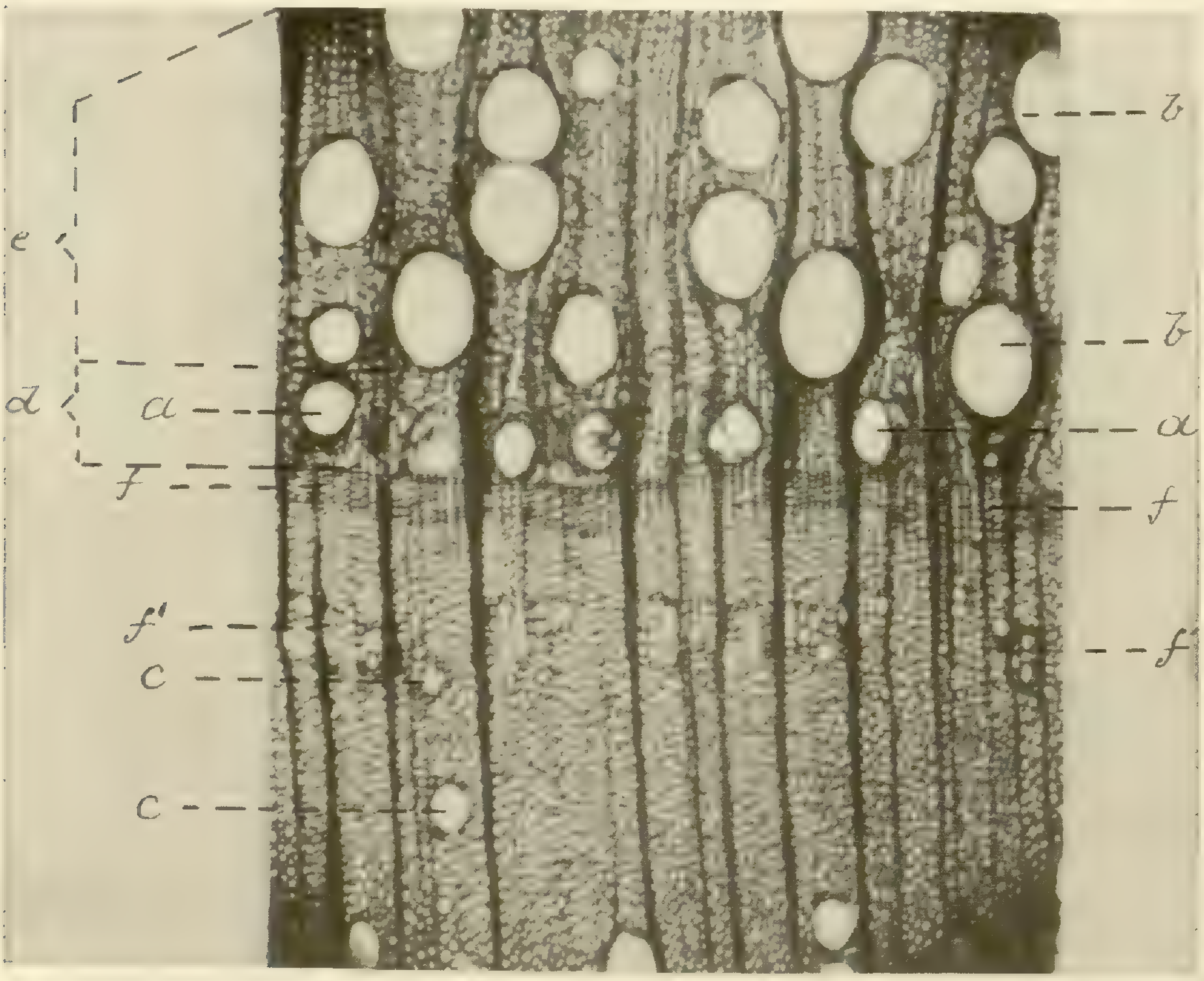


FIG. 1.—*Catalpa teasi.* Transverse section, × 44. *a*, vessels of the primary zone showing small size and few thyloses; *b*, vessels of the secondary zone abruptly much larger and chiefly devoid of thyloses; *c*, the greatly reduced and widely scattering vessels of the last growth of the season; *d*, narrow zone of thin-walled cells of the spring wood: *e*, cells of the summer wood; *f*, zone of spiral and scalariform tracheids forming a limiting layer of uniform width and chiefly without radial extensions, but repeated at *f'* in a second zone centering in the greatly reduced and more numerous vessels.

to what extent the external alterations attendant upon hybridization correspond with internal structural changes. It was felt that the answer to this question might very largely contribute to a solution of the difficult problems relating to the origin of species by either mutation or hybridization, and admit of a more precise limitation of the characters which define a species. The

importance of this latter point of view was the more strongly impressed upon me because, in the course of studies relating to the recognition of species among the North American Coniferales as determined by the anatomy of the woody axis, I had been obliged to adopt the working hypothesis that there are no varietal forms in the sense commonly employed and as expressed in variations of the external organs, and that where these variations arise, they define species as certainly, though not as conspicuously as in other cases. Fortunately I already had in my possession, wood of *C. bignonioides* and *C. speciosa*, while fresh material of the latter was also obtained from trees growing in the grounds of McGill University. About twenty years ago, a specimen of Teas hybrid was planted out in the College grounds, and it has proved perfectly hardy up to the present time, though two other specimens planted about eight years ago were completely killed during the two winters of 1902 and 1903. Recently Mr. Burton Landreth of Bristol, Pa., who possesses a growth of *C. kæmpferi*, very kindly sent me a specimen of wood, and it has thus become possible to bring the wood structure of the hybrid into direct comparison with that of the three species among which its parents are to be found. Later specimens of *C. kæmpferi* from Mr. J. G. Jack of the Arnold Arboretum, have also enabled me to institute more extended comparisons. Before proceeding to a discussion of the results obtained, it will be desirable to recall the essential features of the hybrid as given by Sargent, and to see the direction in which such evidence tends.

"The hybrid is an erect, vigorous and rapid growing tree, with the thin, scaly bark of the American species. The leaves of this tree are much larger than those of either of its parents, having, when they first appear, the velvety character and purple color peculiar to those of the Japanese plant, and the reddish spot at the insertion of the petiole with the leaf blade which characterizes that species. They more generally resemble those of the Japanese species in shape, color and texture, while the pubescence which covers the lower surface is almost intermediate in character between that of the American and of the Japanese species. The inflorescence is much larger than that of the American or of the Japanese plants, being fully twice as

large as that of *C. bignonioides* and more than three times the size of *C. kæmpferi*. The flowers are intermediate in size; in color and markings they most nearly resemble those of the American species, although a tinge of yellow in the throat of the corolla points to their Japanese descent. The fruit of the hybrid is almost intermediate in size between those of the two parents, as are the seeds, which are perfectly fertile and often

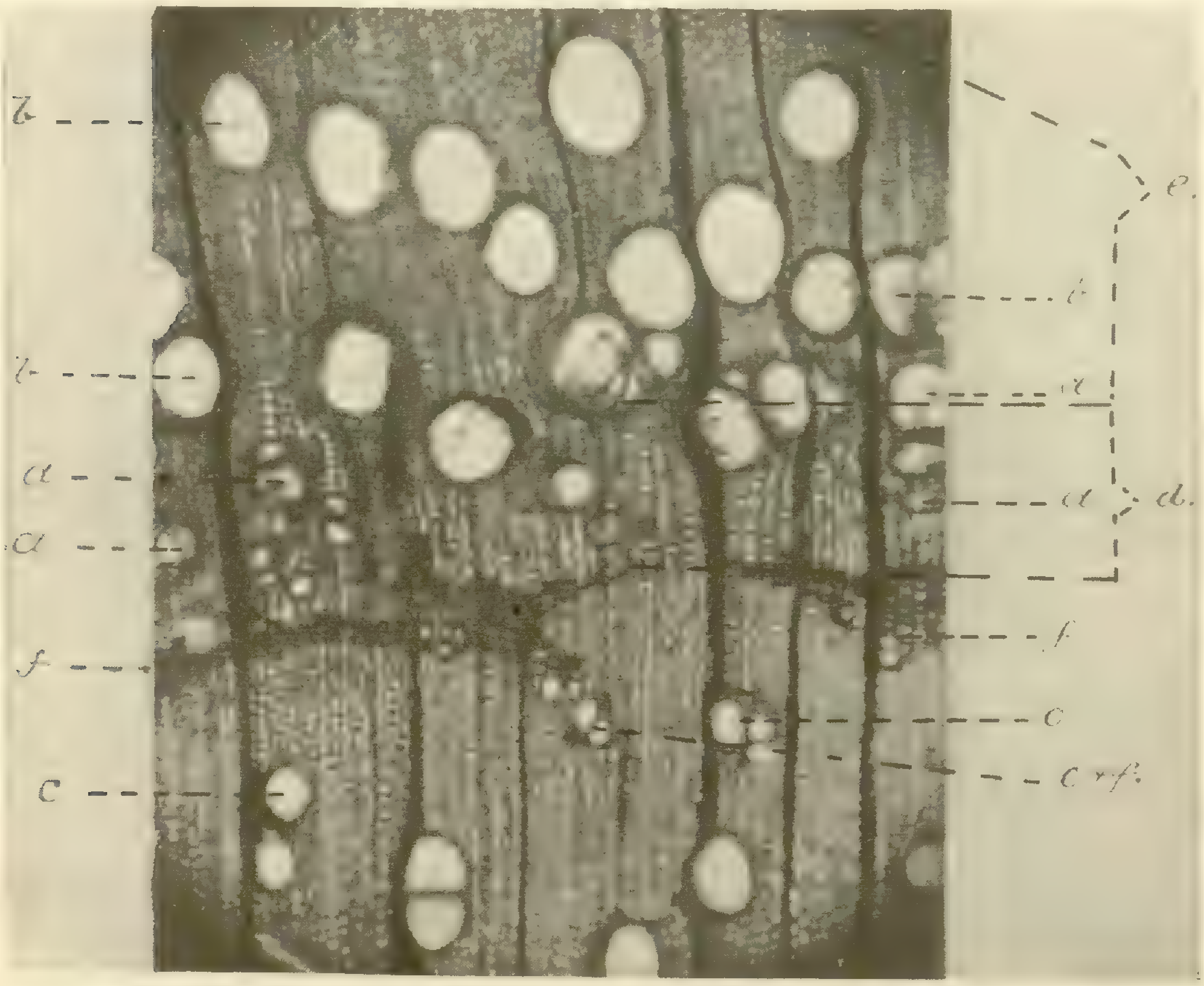


FIG. 2.—*Catalpa kæmpferi.* Transverse section, × 44. *a*, vessels of the primary zone with thyloses; *b*, vessels of the secondary zone showing great increase in size and diminution of the thyloses; *c*, vessels of the last of the season's growth; *d*, thin-walled cells of the spring wood; *e*, smaller and somewhat thicker-walled cells of the summer wood; *f*, zone of spiral and scalariform tracheids limiting the growth ring and showing radial extensions in connection with the last small vessels.

reproduce the original form in every particular. When, however, seedlings show a tendency to vary from the original form, the variation is generally in the direction of the Japanese rather than of the American parent."

"The hybrid is a more vigorous tree than either of the American or the Japanese species, and it grows rather more rapidly.

Of its value as an ornamental tree there can be no doubt. Its larger size and more rapid growth, its better habit and more showy inflorescence, make it a far more valuable ornamental tree than the Japanese species; it is more hardy than either of the North American species, and although the flowers are smaller, the panicles and the number of the individual flowers are much larger." The inflorescence of the hybrid is also remarkable for

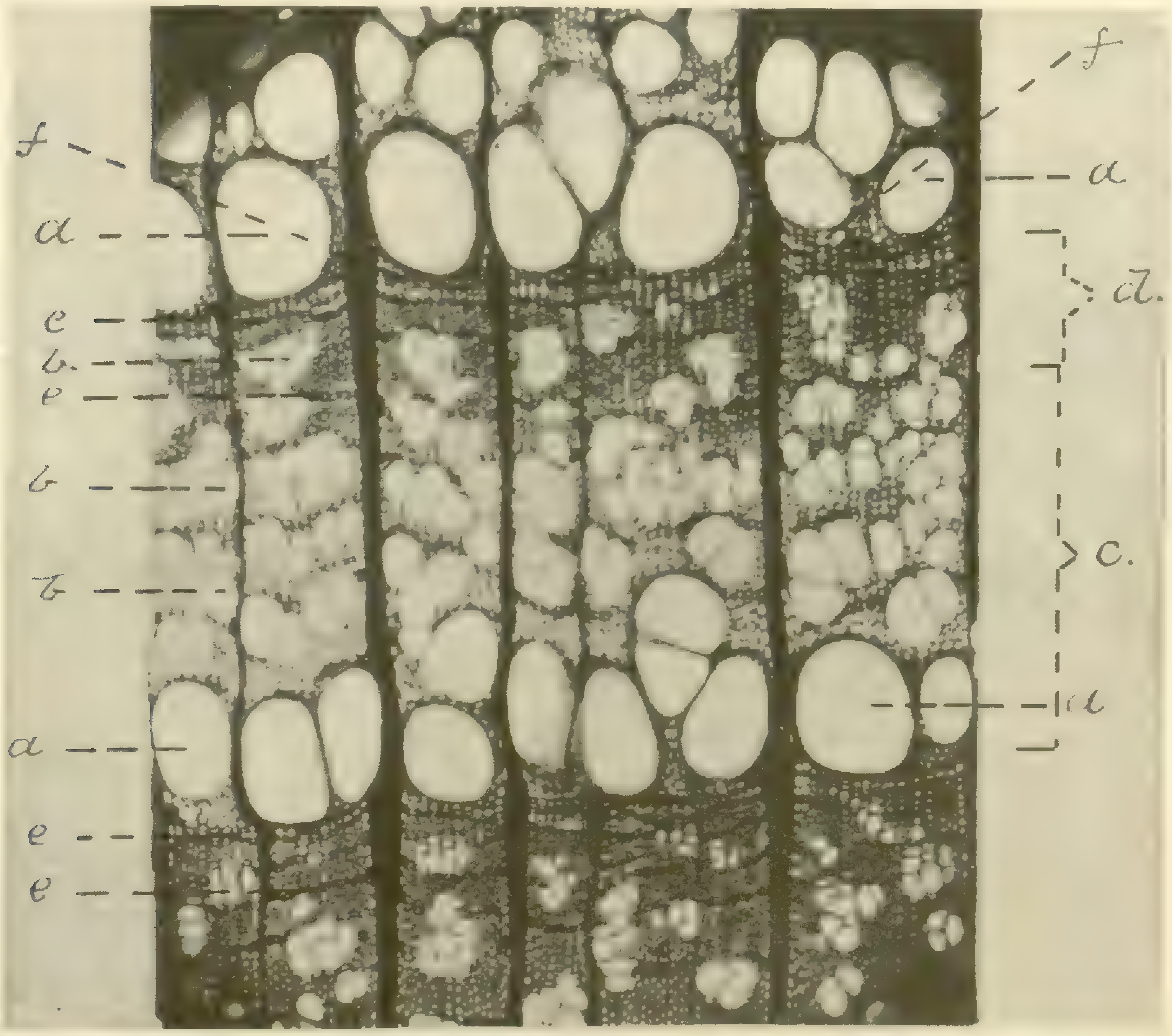


FIG. 3.—*Catalpa speciosa.* Transverse section, × 44. *a*, very large vessels of the primary zone without thyloses; *b*, small and much compounded vessels of the secondary zone, rather abruptly terminated in the outer region of the growth ring; *c*, the broad zone of the spring wood; *d*, the narrow zone of the summer wood; *e*, tangential and concentric bands of resinous wood parenchyma; *f*, the narrow, limiting zone of wood tracheids.

its prolonged duration which extends from June until September as presented by specimens grown here.

We may now turn to a study of the internal structure of the hybrid and of the three related species in order to determine (1) if the crossing has made an impress upon the anatomical structure, or if it is simply expressed in external characteristics; (2)

if there is any anatomical evidence which will determine the species with which *C. kæmpferi* was crossed; and (3) if this evidence bears any relation to the fixity of the form and in any way defines a new species. To this end it will be necessary to elaborate the separate diagnoses and compare them with one another, as also with differences in color, form, and texture as applicable to the leaves and flowers.

TEAS HYBRID (Figs. 1, 5).

Transverse.— Growth rings very broad, the spring wood thin but the distinction between it and the summer wood not clearly recognizable. The wood cells of the earliest growth sometimes tangentially elongated, in more or less obvious radial rows and rather large with rather thin walls: the structure of the later growth chiefly the same throughout the growth ring, the cells hexagonal, in somewhat definite radial rows, not thick-walled, very variable in size with little or no diminution toward the outer limits. Wood parenchyma confined to the composition of the vessels and to the earliest spring wood where the cells become distinctly larger and more resinous. Wood tracheids prominent, squarish, in very definite radial rows, forming a narrow zone of about six elements on the outer face of the growth ring, but locally extended radially inward opposite the smaller vessels with which they join so as to form tracts of variable width: also uniting with the smaller vessels to form a second and more internal, discontinuous zone of very irregular width and form. Vessels at first medium and forming a single layer with strongly developed thyloses: becoming abruptly larger in the second layer, radially oval or oblong and chiefly single, but sometimes 2–3 compounded radially and tangentially and largely devoid of thyloses: soon diminishing in size and number, radially compounded and much scattered in irregular groups of 2–6 throughout the growth ring, finally reduced somewhat abruptly in the last growth of the season to the dimensions of tracheids with which they coalesce into irregular tracts. Medullary rays prominent, numerous, somewhat resinous especially in the spring wood, 1–3 cells wide, distant upwards of 178 μ.

Radial.— Medullary rays somewhat resinous, the cells straight, rather uniform in height, very variable in length and from 3–4 times longer than high, or again very short and much higher: the upper and lower walls rather thick and finely pitted; the terminal walls straight or curved and finely pitted; the lateral walls not pitted except opposite vessels and then with small, numerous, oval and unequal pits. Tracheids of the limiting zone with spiral and scalariform structure which merges into 1–2 rows of simple pits on the radial walls. Wood parenchyma somewhat resinous and exceedingly variable; when adjacent to the spiral tracheids of the summer wood, very

narrowly cylindrical, when adjacent to vessels, usually short cylindrical and bearing numerous transversely oval or oblong pits on the radial walls. Vessels often much shorter than broad, the radial walls with multiseriate, hexagonal pits throughout, the orifice transversely oblong.

Tangential.— Rays very numerous, low to medium, 1–3 cells wide, somewhat resinous; the cells chiefly oblong, rather thin-walled, those of the extremities much larger and more variable. Vessels with multiseriate, hexagonal or more commonly oval, bordered pits which frequently become simple, distant, and transversely oval or oblong. The tangential walls of the wood parenchyma with numerous transversely oval or oblong pits. Tracheids often devoid of spiral and scalariform structure which is replaced by upwards of 3 rows of simple pits.

The features thus described will be found in the figures of

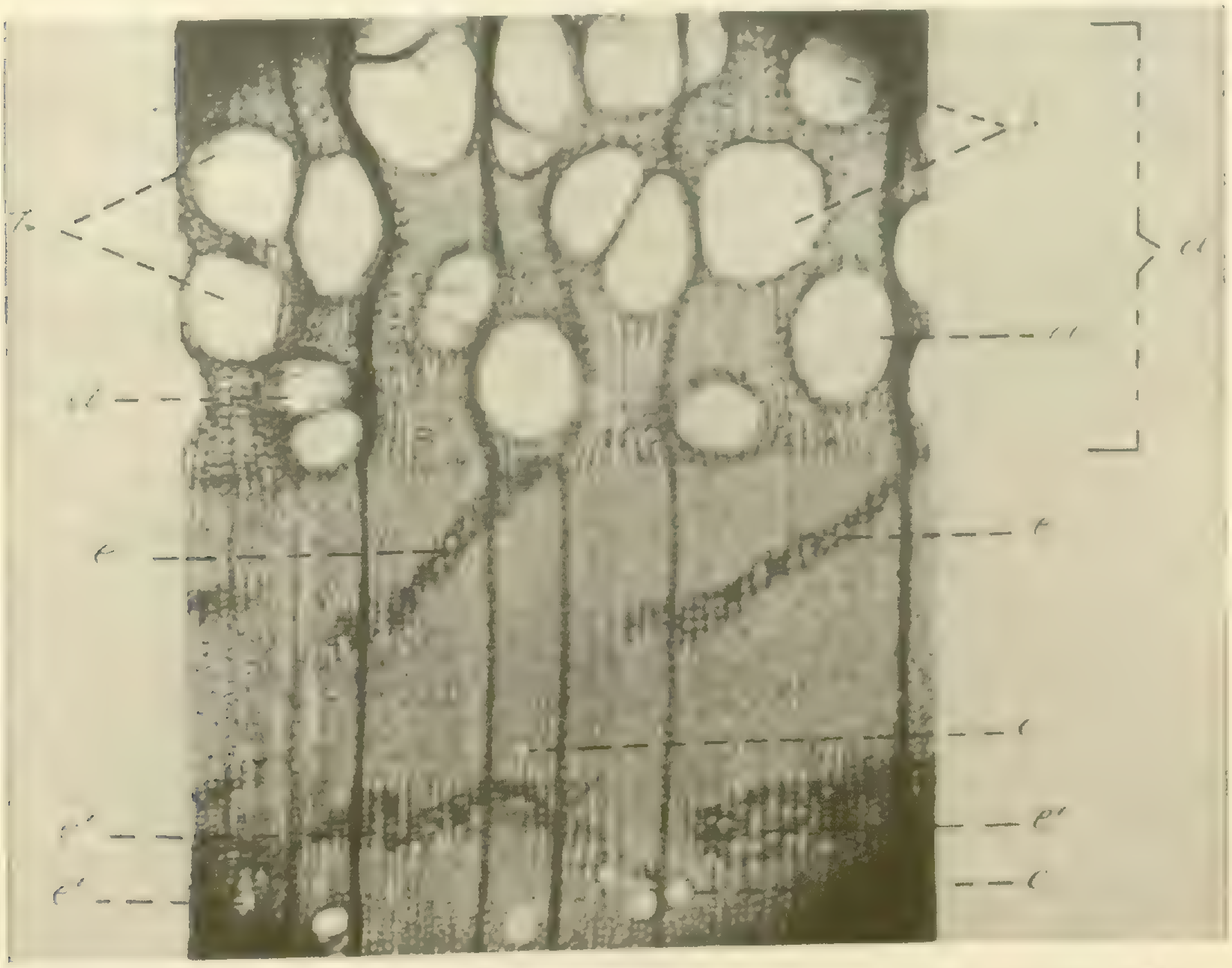


FIG. 4.—*Catalpa bignonioides.* Transverse section, × 44. *a*, very large vessels of the primary zone showing few thyloses; *b*, the vessels of the secondary zone chiefly without thyloses; *c*, the greatly reduced and distant vessels of the summer wood which do not appear prominently within a wide zone; *d*, the broad zone of the thin-walled cells of the spring wood; *e*, diagonally radial tracts of spiral and scalariform tracheids connecting with the outermost and most reduced vessels; *e'*, tangentially extended tracts of tracheids centering in larger vessels and forming an almost continuous, secondary zone.

the transverse and longitudinal sections. As one of the parents of this hybrid is known to be *C. kæmpferi*, its diagnosis may be

given and brought into direct comparison in order to ascertain what characters have been derived from it. By elimination it will then be possible to refer the remaining characters to either *C. speciosa* or *C. bignonioides*.

C. kæmpferi (Figs. 2, 6).

Transverse.— Growth rings very broad. Differentiation of the spring and summer woods well defined (?), the latter constituting the bulk of the growth ring and defined by a somewhat abrupt transition in the form, size, and thickness of wall of the component cells. The spring wood composed of large, variable, squarish-hexagonal and tangentially elongated, non-resinous, and thin-walled cells which form a limiting zone external to the previous growth ring; soon replaced by the somewhat abruptly smaller, rather thin-walled, hexagonal and radially elongated cells of the summer wood which diminish almost imperceptibly toward the outer face of the growth ring. Wood parenchyma strictly confined to the composition of the vessels. Tracheids conspicuously squarish, rather uniform, in regular radial rows, more or less resinous, rather thick-walled and forming a limiting layer upwards of six cells thick on the outer face of the summer wood, or opposite the most recently formed small vessels, joining with the latter to form radially extended tracts of irregular form and extent, or even forming detached groups centering in small vessels, so as to form a second zone of imperfect development. Vessels somewhat numerous and scattered throughout the growth ring; those of the early spring wood with strongly developed thyloses; at first rather small, numerous and round, but abruptly enlarging with the corresponding transition from the spring to the summer wood cells, and becoming oval or radially extended and 2–3 compounded in radial series, predominant; again abruptly reduced in size and number, sometimes radially 2–3 seriate, and thence continuing without much variation to the region of the outer summer wood where they are once more abruptly reduced in size and there give rise to the terminal layer of tracheids. Medullary rays prominent, sparingly resinous, 1–3 cells wide, distant upwards of 427 μ.

Radial.— Medullary rays sparingly resinous; the cells within the region of the early spring tracheids chiefly short; isodiametric; the upper and lower walls rather thick and strongly pitted; the terminal walls thicker and more strongly pitted; the lateral walls with numerous small pits in more or less definite radial series; in older parts of the growth ring the cells increase greatly in length, except the marginal ones which remain short and become much higher, the pits on the lateral walls opposite vessels become much larger and oval. Wood parenchyma of the spring wood composed of short and thin-walled cells which bear rather numerous, transversely oval, simple pits on the radial walls; those of the vessels of later

growth much longer and narrower. Tracheids of the summer wood narrow, spiral, scalariform, and pitted, and showing all transitional forms from simple spirals to hexagonal bordered pits in 1–3 series. The radial walls of the vessels with numerous hexagonal pits having rather large, transversely oval or oblong openings.

Tangential.— Medullary rays rather numerous, resinous, low to medium and 1–3, chiefly 2 cells wide; the cells rather thick-walled, hexagonal. Tangential walls of the vessels with numerous and variable, transversely oval, oblong or long linear, often simple pits. The tangential walls of the spring parenchyma with numerous round or transversely oval, chiefly simple pits; those of the early spring wood cells with transversely linear, narrow and rather numerous pits.

A comparison of the transverse and tangential sections for this species, with those for the hybrid, makes the general relations of the two very obvious, but a more critical examination of them is necessary. In each case the wood is characterized by the great breadth of the growth ring. In *C. kœmpferi*, the thin-walled spring wood constitutes a rather narrow zone representing but a small volume of the total growth for the season. Precisely the same is also true of the hybrid with the difference that the volume is reduced to about one half what is to be found in the former, showing the definite influence of one parent. In each case the wood parenchyma is confined to the composition of the vessels or to the earliest spring wood, and there is no feature in them which can be directly ascribed to *C. kœmpferi*. A very definite connection between *C. kœmpferi* and the hybrid, appears in the distribution of the tracheary tissue which, in the latter, forms a well defined limiting layer occupying the same position as in the former but characterized by greater uniformity of width. This is undoubtedly due to *C. kœmpferi* in the first instance, but ultimately it is to be regarded as a resultant effect from the interaction of the two parents as will appear later. In addition to the limiting zone of tracheids which sometimes extends radially inward as in *C. kœmpferi*, though not generally to the same extent or so frequently, it is to be noted that in the hybrid there is a second and more internal zone of tracheary tissue which centers in the small vessels of the outer summer wood and which forms tangentially extended tracts of a very well defined character. This feature is one of the most prominent structural

changes, and it points with great force and directness to the influence of some other parent than *C. kæmpferi*, although this has also exerted an influence. In the distribution, size, and character of the vessels, there are but few features which serve to guide us in forming a conclusion, but it will be noted that the

FIG. 5.—*Catalpa teasi.* Tangential section, × 61. Showing vessels with few or no thyloses, and the rather numerous and medium rays of lenticular form, 2–3 cells wide.

conspicuous thyloses of *C. kæmpferi* have practically disappeared in the hybrid though retained in the initial row of vessels which have increased slightly in size and are confined to a much narrower, radial zone. This points without doubt to the influence of the other parent. In the outer regions of the growth ring, the vessels are seen to be conspicuously smaller and on the

whole, more scattering in the hybrid than in *C. kæmpferi*, a feature undoubtedly derived from the other parent. The medullary rays offer no evidence of value in favor of either parent, since in each case they present the same features of structure.

In the structure of the medullary ray as presented in radial section, some features are worthy of consideration. The generally short, isodiametric cells of *C. kæmpferi* are more commonly replaced in the hybrid by longer and very variable cells, the upper, lower, and terminal walls of which are marked by fine pits, all of which features must have been derived from another parent than *C. kæmpferi* in which the walls are distinguished by coarse pits. While in the latter species the pits on the lateral walls of the cells are rather large and oval, in the hybrid they become small, numerous, and unequal. In each case the spiral and scalariform tracheids of the summer wood show transitional forms leading to the development of pits, but while in *C. kæmpferi* these latter structures are hexagonal, bordered, and in 1–3 series, in the hybrid they are usually simple and in 1–2 rows only, thus showing a modification which must be attributed to the other parent.

In a tangential section the medullary rays correspond in approximate number and height, as also in the number of series of cells entering into their composition, but while in *C. kæmpferi* the cells are rather thick-walled and hexagonal, in the hybrid they are rather thin-walled and oblong, the marginal cells becoming much higher and more variable. From this comparison it is obvious that *C. kæmpferi* has influenced the hybrid in very definite ways, while it is equally clear that the latter presents a number of characteristics which could have been derived only from *C. speciosa* or *C. bignonioides*, and in order to determine which, we may next compare *C. speciosa*. An inspection of a transverse section of this wood shows that it possesses features of structure which are in very marked contrast to what may be found in either of the preceding species, but in order to make these differences clear, a diagnosis may be given before proceeding to a detailed comparison.

C. speciosa (Figs. 3, 7).

Transverse. — Growth rings narrow, rather uniform, consisting of about one half spring and one half summer wood distinguished by their variations in (1) size of cells, (2) the thickness of the walls, and (3) the disposition of the cells. Cells of the spring wood large, thin-walled, hexagonal or sometimes tangentially extended, in somewhat obvious radial rows; those of the summer wood hexagonal, uniform, thick-walled, smaller and *not at all* in radial rows. Wood parenchyma dark and resinous, the cells forming tangential and concentric series at frequent intervals, chiefly in the summer wood. Wood tracheids thin-walled, few, in two or three rows terminating the growth ring as a layer of uniform thickness. Vessels of the earliest spring wood at first very large, oval or round, rarely compounded, and chiefly devoid of thyloses; quickly reduced and soon compounded in radial and tangential series and finally reduced to about twice the diameter of the wood cells; very numerous throughout the growth ring to which they impart an element of great porosity. Medullary rays somewhat numerous, dark, 1–several cells wide, distant upwards of 445 μ.

Radial. — Wood parenchyma abundant, the cells in parallel rows, 14.6 μ to 100 μ wide; sparingly resinous, the radial walls with rather numerous, small and simple pits. Medullary rays sparingly resinous; the cells chiefly uniform in height except the marginal ones which are very variable, short in the summer wood and upwards of 2½ times the height, or in the spring wood several times longer than high, the upper and lower walls sinuately unequal, rather thick, conspicuously pitted; the terminal walls straight, strongly but rather finely pitted; the lateral walls devoid of pits except opposite vessels where they commonly show a fine sieve-plate structure or are otherwise numerously pitted. Vessels chiefly rather short but very variable, the terminal walls rather thick but not pitted; the radial walls with multiseriate, very variable, hexagonal, round, oval, transversely oval or oblong, often much elongated and distant pits, the orifice finally becoming a much elongated, narrow slit without a border, thus showing transitions into scalariform structure. Radial walls of the spring wood cells with rather small, longitudinally oblong pits in vertical series. Tracheids of the summer wood interspersed with wood parenchyma, the radial walls spiral and scalariform and merging into rather small, oval, bordered pits upwards of 5-seriate.

Tangential. — Medullary rays numerous, low to very high, often equal to 2 mm., dark, resinous, one to unequally multiseriate and upwards of 5 cells wide; the cells small, round or oval, thick-walled, variable, the terminal cells commonly oblong. Wood parenchyma of the spring wood composed of short cylindrical cells with square or fusiform ends, the tangential walls with numerous, multiseriate but small, transversely oval, bordered pits. Tangential walls of the vessels with numerous small, multiseriate, hexagonal or transversely oval, bordered pits.

A careful analysis of this diagnosis shows that the most marked deviations from the characters embodied in the hybrid, are to be found in (1) the growth rings which are always several times less in radial extent and far more porous, (2) in the character of the initial layer of vessels which are always very large and devoid of thyloses, (3) in the character of the vessels of later

FIG. 6.—*Catalpa kæmpferi*. Tangential section, × 61. Showing vessels with numerous thyloses and the low, rather numerous rays of lenticular form, upwards of three cells wide.

growth, which are always much compounded and much smaller, their reduction from those of the initial layer being abrupt, (4) in the presence of numerous resinous wood parenchyma cells which lie in definite, concentric zones of one cell in width, (5) in the tangential aspect of the medullary rays which are exceedingly variable in height, of very unequal width and upwards of

5 cells wide. These features are of so pronounced a nature as to leave no doubt whatever as to the fact that *C. speciosa* is not in any way concerned in the production of the hybrid, since none of its characteristics are to be met with in the latter. It now becomes necessary to determine as a final factor, whether the features of the hybrid which we have already seen cannot be accounted for as being derived from *C. kæmpferi*, are in any way attributable to *C. bignonioides*.

C. bignonioides (Figs. 4, 8).

Transverse.— Growth rings very broad. The summer wood not sharply defined but distinguishable by (1) the smaller size of the wood cells, (2) the reduction of the vessels, and (3) the presence of groups or tracts of tracheids. Spring wood composed of large, variable, hexagonal, and tangentially elongated cells in somewhat obvious radial rows, the walls thin; soon replaced by the smaller and radially extended cells of the summer wood which diminish very gradually toward the outer limits of the growth ring. Wood parenchyma confined to the structure of the vessels. Tracheids rather thick-walled, non-resinous, squarish or tangentially extended, in radial rows confined to the outer portions of the growth ring where they form irregular and tangentially extended tracts of variable, often great extent in two series; the inner rather broad and strictly tangential, the rather large tracts more or less confluent and continuous, the outer formed of narrow, diagonal and chiefly free tracts projected inwardly from the outer limits of the growth ring. Vessels of the spring wood with strongly developed thyloses, at first large, oval or round, single and strongly predominant; soon becoming 2–3 compounded in radial series and steadily diminishing in size, shortly becoming single and more distant, and finally replaced wholly by groups of tracheids. Medullary rays prominent, 1–several cells wide, sparingly resinous, distant upwards of 462 μ.

Radial.— Medullary rays sparingly resinous; in the spring wood the cells are upwards of six times longer than high, the upper and lower walls very thin and barely pitted, the terminal walls thin and finely pitted, the lateral walls with occasional fine and simple pits; in the summer wood the cells are often not much longer than high, the upper and lower walls finally rather thick and strongly pitted, the terminal walls rather thick and finely pitted, the lateral walls when opposite vessels with rather small and commonly numerous, oval, simple pits in more or less definite radial series. Wood parenchyma of the first spring wood composed of short-cylindrical and rather broad cells, the radial walls with numerous, transversely oval or oblong, simple pits. The tracheids of the summer wood narrowly cylindrical and showing all transitional forms from spiral and scalariform to

small, transversely oval, and simple pits, or 2-seriate hexagonal bordered pits. Radial walls of the cells of the summer wood commonly with small, lenticular pits showing a cross. Radial walls of the vessels with multiseriate, hexagonal or even transversely oblong, distant pits, the thyloses with distant, linear and simple pits.

Tangential.— Rays rather narrow, medium to somewhat high, upwards of 3-seriate, the cells all thin-walled, hexagonal. Tangential walls of the vessels with multiseriate, oval pits, the narrow, linear orifice of which is transverse and often exceeding the pit. Pits on the tangential walls of the spring wood parenchyma often simple and transversely oblong.

The growth rings of *C. bignonioides* are seen to be very broad, thus conforming to what also appears characteristic of *C. kæmpferi*, and what arises as a necessary resultant in the hybrid, but constituting a feature entirely wanting in *C. speciosa*. Thus it appears that the growth rings in *C. speciosa* are approximately only one fifth of the radial dimensions in either the hybrid or *C. bignonioides*. While in general terms this difference may be said to exist, it cannot be taken as a differential character of leading importance for the reason that under certain circumstances of growth, the hybrid may develop equally narrow rings. Putting this factor to one side, we then find that the structure of the growth ring affords a very definite means of determining any possible relationship. The region which I consider as probably representing the spring wood, is several times broader than in *C. kæmpferi*, and the contraction of this zone in the hybrid must be viewed as due to the direct influence of the latter species. The vessels of the early spring wood are large and they increase in size for some distance within the limits of the spring wood, so as to form a rather broad zone without any well defined distinction of a primary and secondary zone as appears in *C. kæmpferi* and more prominently in the hybrid, and it is probably correct to say that the limitation in size and distribution which is expressed in the latter, is the direct result of the dominating influence of the large vessels of *C. bignonioides*. The influence of the latter is also expressed in the general distribution of the vessels. In *C. kæmpferi*, *C. bignonioides*, and the hybrid, the vessels gradually diminish in size toward the outer limits of the growth ring, but a comparison of their distribution in the first and last shows that the hybrid occupies an

intermediate position between the first two in such a manner as to show the direct influence of the latter in a reduction of both size and number in the outer summer wood. This feature is again correlated with the distribution of the tracheids. Our diagnoses have shown that in *C. kœmpferi* these elements form

Fig. 7.—*Catalpa speciosa.* Tangential section, × 61. Showing the vessels with rather few thyloses and the exceedingly high rays of variable width, composed of several rows of thick-walled cells.

a limiting zone which is locally increased in thickness in a radial direction opposite the small vessels of the outer summer wood, with which they coalesce to form irregular tracts; or again centering in small vessels so as to form a second zone of small and rather distant tracts. The same feature appears also in *C. bignonioides* but in such a modified form as to constitute a distinc-

tive character. Thus the tracheids lie in two zones. In the outer zone the tracheids form disconnected tracts of variable form and extent, which are rarely connected by a narrow zone of tracheary tissue on the outer face of the growth ring. These tracts are neither radial nor tangential in disposition, but the resultant of these two directions, and as they project diagonally

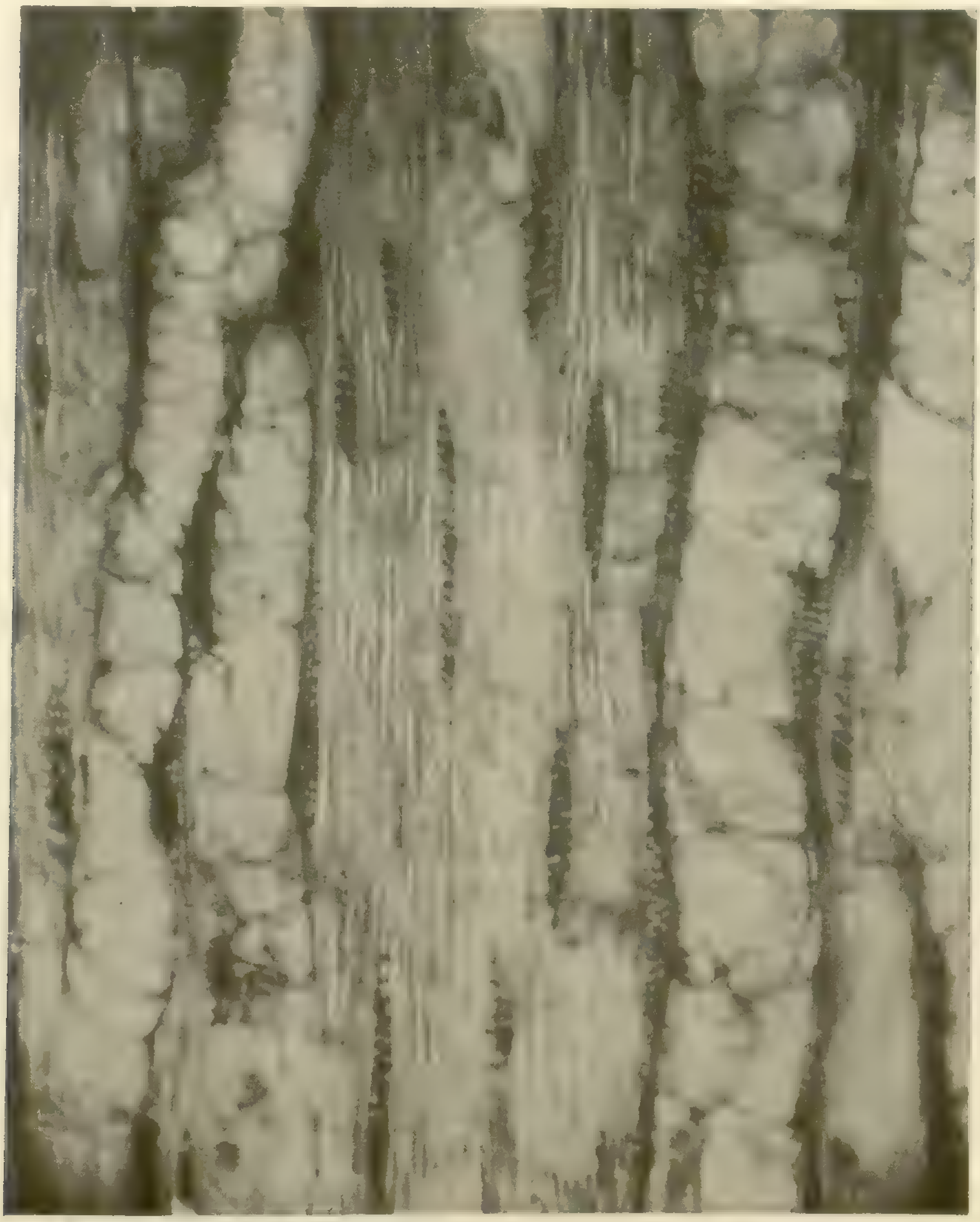


FIG. 8.—*Catalpa bignonioides*. Tangential section, × 61. Showing vessels with numerous thyloses and the medium to rather high, lenticular-oblong rays upwards of three cells wide.

inward, they join with very small vessels which constitute the final phase of such structures in the summer wood. In the second zone of tracheary tissue, the tracheids form tangentially extended tracts of variable form and size which are always connected with vessels of larger dimensions than those lying in the outer zone, and these tracts form an almost continuous series.

In the hybrid two such zones are also found. The inner zone is composed of tangentially extended tracts of variable form and size centering in vessels corresponding to those of the inner zone of *C. bignonioides* and presenting features which are intermediate between those of the latter species and *C. kæmpferi*. The direct influence of *C. bignonioides* is thus made very apparent. The outer zone of tracheids consists of a limiting layer of rather uniform thickness and generally devoid of vessels. Here and there a tendency to radial extension may be noted, but there is nowhere anything approaching what is to be met with in either *C. kæmpferi* or *C. bignonioides*, and the actual structural condition must be regarded as a resultant from the interaction of these two species, in which a somewhat equal influence appears to have been exerted.

In the radial aspect of structure, the influence of *C. bignonioides* is definitely expressed in the hybrid in (1) the more variable dimensions of the ray cells; (2) in the less coarsely pitted walls; (3) the 2-seriate character of the pits on the radial walls of the tracheids. In the tangential aspect, the influence of the same species is manifested in the thin walls of the ray cells, while the influence of *C. kæmpferi* is expressed in the character of the marginal cells. Other features of a minor character also contribute to the general results thus indicated, a summary of all of which may most conveniently be presented in a tabular view, from which I have excluded all characters common to the hybrid and to the three species.

Comparison of structural variations in Catalpa.

	Teas Hybrid.	*C. kæmpferi.*	*C. bignonioides.*	*C. speciosa.*	No.
Transverse.					
Growth rings very broad	×	×	×	—	3
Growth rings narrow, uniform . . .	—	—	—	×	1
Spring and summer wood obvious . .	—	×	—	×	2
Spring and summer wood not distinguishable or locally defined . . .	×	—	×	—	2
Cells of summer wood uniform, thick-walled, *not at all* in radial rows . .	—	—	—	×	1
Cells of summer wood variable, thin-walled in radial rows	×	×	×	—	3

	Teas Hybrid.	*C. kæmpferi.*	*C. bignonioides*	*C. speciosa.*	No.
Transverse.					
Wood parenchyma confined to the vessels and the earliest spring wood .	×	×	×	—	3
Wood parenchyma in tangential and concentric zones of a single layer throughout	—	—	—	×	1
Wood tracheids in radial rows on the outer face of the summer wood, radially extended opposite and confluent with the small vessels . . .	×	×	—	—	2
Wood tracheids forming two zones .	×	×	×	—	3
Wood tracheids forming irregular tangential tracts	×	×	×	—	3
Wood tracheids in a terminal layer of 2–3 rows	—	—	—	×	1
Vessels of early spring wood with thyloses	×	×	×	—	3
Vessels of early spring wood without thyloses	—	—	—	×	1
Vessels scattered throughout, often radially compounded	×	×	×	—	3
Vessels very numerous, chiefly small, radially and tangentially compound	—	—	—	×	1
Medullary rays 1–3 cells wide, low to medium, uniform	×	×	×	—	3
Medullary rays 1–5 cells wide, variable	—	—	—	×	1
Radial.					
Upper and lower walls of ray cells finely pitted	×	—	×	×	3
Upper and lower walls of the ray cells coarsely pitted	—	×	—	—	1
Tracheids with hexagonal pits in 1–3 series	—	×	—	—	1
Tracheids with 1–2 seriate bordered pits	—	—	×	—	1
Tracheids with hexagonal, very variable, multiseriate pits	—	—	—	×	1
Tracheids with simple pits in 1–2 rows	×	—	—	—	1
Vessels with multiseriate, hexagonal pits	×	×	×	—	3
Vessels with variable, often much elongated, slit-like pits merging into scalariform structure . . .	—	—	—	×	1
Tangential.					
Rays 1–3 cells wide, low to medium	×	×	×	—	3
Rays upwards of 5 cells wide, unequally multiseriate	—	—	—	×	1
Ray cells small, thick-walled, variable	—	—	—	×	1
Ray cells oblong, thin-walled . . .	×	—	—	—	1
Ray cells hexagonal, thin-walled . .	—	—	×	—	1
Ray cells hexagonal, thick-walled . .	—	×	—	—	1
Total characters	15	15	14	13	57

Percentages of characters.

(Those common to all are omitted.)

	Number.	Percent.
Hybrid + bignonioides + kæmpferi	10	31.2
Hybrid + speciosa	0	00.00
Hybrid + bignonioides	1	3.12
Hybrid + kæmpferi	1	3.12
Kæmpferi + bignonioides	0	00.00
Kæmpferi only	3	9.4
Bignonioides only	2	6.24
Hybrid only	2	6.24
Speciosa only	11	34.4
Speciosa + bignonioides	1	3.12
Speciosa + kæmpferi	1	3.
Total	32	99.84

From this percentage summary it appears that *C. speciosa* embodies 34.4 % of characters which are peculiar to itself, while *C. kæmpferi* and *C. bignonioides* possess 31.2 % of characters which are not only common to each other but also common to the hybrid, the remaining characters belonging, with one exception, either to these last two species or to the hybrid. From these facts therefore, we are abundantly justified in the following conclusions:—

1. Hybrid characters are expressed in the structure of the vascular cylinder as well as in external alterations of form and color.

2. *Catalpa speciosa* is not in any way concerned in the production of Teas Hybrid.

3. Teas Hybrid Catalpa is the product of a cross between *C. kæmpferi* and *C. bignonioides*, thus confirming the conclusions already reached by Sargent on the basis of external morphology.

4. The dominant characters of the hybrid, as expressed in the internal structure, are those of the Japanese parent as similarly manifested in the external characters.

5. The resultant characters are most strongly exhibited in transverse section, less so in the tangential, and least of all in the radial.

The question still remains unanswered, as to how far this hybrid approaches and satisfies the conditions which define a species. A complete solution of this question would be obtained in the most satisfactory manner by an anatomical study of reverted forms of the hybrid, were it possible to satisfy all the requisite conditions of authenticity, and determine to what extent the anatomical changes already found to characterize the hybrid, revert to the structure of the separate parents. Unfortunately such studies have not been possible under the conditions of the present investigation, and we are therefore compelled to fall back upon such partial evidence as is afforded by the external morphology. Reference to the original description of the hybrid shows that seedlings exhibit a decided tendency to reversion with respect to the character of the flower, and that such tendency is always in the direction of *C. kæmpferi*. This fact makes it clear that the Japanese parent exerts a dominant influence, while it also shows that the characters are not always fully fixed. Reference to the original description, however, makes it clear that such reversion is not displayed by *all* seedlings but only by *some*, results which are within the limits of justifiable anticipation and in strict accord with Mendel's law. Possibly our knowledge of all the changes incident to reversion is not as yet sufficiently complete to admit of a final expression of opinion as to the actual stability of the hybrid and its status as a species, but it may be kept in mind that while some seeds exhibit reversion, others come true to the hybrid form which is capable of perpetuating itself in succeeding generations. There is in this case no reason for supposing that this is any less a true species than large numbers of plants in which hybridization is an important factor as the starting point for a new line of development. With the abandonment of the old idea of fixity of species, and more particularly in the light of Mendel's law, we are led to see that in any case of hybridization there must be large numbers of progeny which, through reversion, ultimately disappear, while comparatively few acquire such stability as to survive in the form of what must be regarded as definite species. It is only on such grounds that we are justified in regarding as species the numerous and but slightly differentiated forms of the

willows, asters, and the Juglandaceæ which Prof. Sargent directs attention to as undoubtedly illustrating the effects of hybridization. Such potential species have always been a source of great difficulty to the systematic botanist who has been unable to properly define their limitations in such a way as to make them recognizable at all times and under all circumstances. The recent separation of six new species of violets from *V. cucullata* by Greene,[1] and the large number of species of Cratægus now recognized by Prof. Sargent can only be explained either as mutant forms or as new species according to the Mendelian law. Their acceptance as valid species shows that our former notions of the relations of hybrids and species have undergone radical change, and that we can no longer accept the limitations which were formerly supposed to be valid. If we are to accept as species those forms only in which there is no reversion to the parental type, and in which there is an absolute fixity of characters, then the hybrid in question cannot be regarded as a species; but if, on the other hand, we accept as species, as is now the custom, those forms which possess strongly defined potentialities, and in which the tendency to reversion is relatively weak, then the hybrid in question must be held to be a valid and distinct species as much as any other plants so defined, and in this sense it should be known as *C. teasi*, n. sp.

It only remains on the present occasion, to define the diagnosis for the genus Catalpa, and present a differential key for the recognition of the species, as follows: —

CATALPA.

Transverse.— Growth rings chiefly broad; the summer wood usually much exceeding the spring but the limitations not sharply defined. Wood parenchyma more or less resinous, often strongly so, generally associated with the vessels but sometimes forming concentric zones. Wood tracheids squarish and forming a limiting layer on the outer face of the growth ring from which irregular tracts may project radially inward, or again form a secondary zone. Vessels numerous, radially or sometimes tangentially compounded, with or without thyloses.

Radial.— Medullary rays somewhat resinous; the cells often higher than

[1] *Ottawa Nat.*, vol. 12, p. 181.

long, their upper, lower, and terminal walls rather thick and obviously pitted, their side walls pitted opposite vessels. Tracheids of the limiting zone spiral and scalariform and exhibiting transitions to bordered pits. Wood parenchyma cells variable but narrowly cylindrical, the radial walls with numerous transversely oval, simple pits. The radial walls of the vessels with numerous, multiseriate, hexagonal pits.

Tangential.— Rays usually numerous and multiseriate, the cells small and thick-walled.

Synopsis of Species.

Resinous wood parenchyma in concentric zones one cell thick.
  Vessels of the primary zone large, oval, devoid of thyloses: those of the secondary zone small, very numerous, much compounded.
    Rays (tang'l) numerous, low to very high, unequally multiseriate, upwards of 5 cells wide.
      Ray cells (tang'l) small, round or oval, thick-walled, variable.
1. *C. speciosa.*

Wood parenchyma sparingly resinous, the cells scattering and chiefly confined to the composition of the vessels.
  Vessels chiefly large, not much compounded, scattering and gradually diminishing toward the outer face of the growth ring.
    Rays (tang'l) numerous, medium, 1–3 cells wide.
      Wood tracheids in two zones: the outer composed of chiefly free, radially diagonal tracts; the inner of rather broad, variable and tangentially extended contiguous tracts forming an almost continuous zone.
        Vessels of the primary zone large, oval or round, with few thyloses.
          Ray cells (tang'l) thin-walled, hexagonal.
2. *C. bignonioides.*

    Rays (tang'l) numerous, low to medium, 1–3 cells wide.
      Wood tracheids in one zone, forming a continuous limiting layer with radial extensions opposite small vessels with which they unite, sometimes giving rise to detached groups which thus form a second, discontinuous zone.
        Vessels of the primary zone small to medium, round, with strongly developed thyloses, abruptly enlarging in the secondary zone and finally becoming 2–3 compounded radially.
          Ray cells (tang'l) rather thick-walled, hexagonal.
3. *C. kæmpferi.*

      Wood tracheids in two well defined zones: those of the outer forming a continuous and rather uniform limiting layer upwards of 8 elements thick; those of the inner zone form-

ing a discontinuous tract of variable form and width.
Vessels of the primary zone in a single layer, small with sparingly developed thyloses, becoming abruptly larger and devoid of thyloses in the second zone, and finally sparingly compounded.
Ray cells (tang'l) chiefly oblong, rather thin-walled.
4. *C. teasi*, n. sp.

THE OCCURRENCE AND ORIGIN OF AMBER IN THE EASTERN UNITED STATES.[1]

ARTHUR HOLLICK.

A Recent Discovery of Amber in the Cretaceous Deposits at Kreischerville, N. Y.

Preliminary Note.— A recent discovery of amber in considerable quantity, in connection with the Cretaceous deposits at Kreischerville, Staten Island, N. Y., may be found briefly recorded by the writer in the *Proceedings* of the Natural Science Association of Staten Island for November 12th, 1904, but without any extended description or discussion. The discovery, however, was found to have aroused an unexpected interest in the subject, and the preparation of this paper was suggested.

Geologic Age and General Description of the Deposits.— The deposits in question consist of clays and sands which represent a part of the eastward extension of the Amboy clay series of New Jersey and are included in the Raritan formation, which is generally recognized as middle Cretaceous in age and approximately the equivalent of the Cenomanian of Europe, the lower Atane beds of Greenland, and the Dakota group of the West.

At Kreischerville they have been extensively excavated for economic purposes and in what is known as the Androvette pit a section was recently exposed, consisting of irregularly bedded clays and sands, referable to the geologic horizon above mentioned, overlain unconformably by more recent sands and gravels, the entire series showing more or less disturbance by glacial action. A view of a portion of the pit is shown in Plate 1.

Conditions Under Which the Amber Occurs.— The amber occurs in a stratum or bed, characterized by layers and closely packed masses of vegetable débris, consisting of leaves, twigs,

[1] Read before the Botanical Society of America, Philadelphia meeting, Dec. 30, 1904. Investigations prosecuted with the aid of a grant from the Society.

PLATE I.—Section in Androvette pit, Kreischerville, Staten Island, N. Y., showing unconformity between Cretaceous clays and sands below and Tertiary or Pleistocene sands and gravels above.

and fragments of lignite and charred wood. Pyrite, in nodules, is also a prominent constituent. This bed, where exposed in vertical section, appears as if lens-shaped, having an indicated maximum thickness of about 3 feet and a lateral extent of 18 feet or more. The face of the pit at this place is about 20 feet high and the lower part of the bed is about 1 foot from the present floor of the pit. The section in which the bed is exposed is shown in Plate 2. It is immediately adjacent to the left of the section shown in Plate 1.

Most of the amber was found in a relatively thick accumulation of finely comminuted lignite and charred wood, of limited extent, through which it was irregularly distributed. This matrix yielded nearly all of the larger specimens and a majority of the smaller ones. The remainder were obtained from the relatively thinner layers of leaves and twigs. A piece of the lignitic matrix, with fragments of amber enclosed, is shown on Plate 3, Fig. 34.

Characters of the Amber.— A large part of the amber is in the form of drops or "tears," examples of which may be seen on Plate 3, Figs. 1–23, but irregularly shaped fragments, varying in size from a large pin's head to a hickory nut, are the most abundant. They are generally more or less transparent and yellow or reddish in color, but many are opaque and grayish white. Some of the best examples of the former are shown on Plate 3, Figs. 24–32, and a large piece of the latter on Plate 3, Fig. 33. The finest specimen in size, color, and transparency, represented by Fig. 32, is about 6 cu. cm. in volume. All of the figures on Plate 3 are of natural size.

Disposition of the Specimens.— Most of the specimens collected are deposited in the museum of the New York Botanical Garden and the remainder in that of the Natural Science Association of Staten Island. The only other specimens from this vicinity which I have been able to locate are included in the collections at Columbia University. These are three in number and are labeled respectively, "Marl pits, Squankum, N. J.," "Kirby's marl pit, Harrisonville, N. J.," and "Valentine's clay pit, Woodbridge, N. J." The last mentioned is of good quality and is about the size of a filbert nut.

Plate 2.—Section in Androvette pit, Kreischerville, Staten Island, N. Y., at extreme left of Plate 1, showing stratification of the Cretaceous deposits and bed, indicated by the pick, in which leaves and amber occur.

Previous Records of the Occurrence of Amber in the Eastern United States.

It is probable that amber is far more common in the Cretaceous deposits of the eastern United States than is generally supposed. The amount that may be obtained at the Kreischerville locality alone is considerable, as evidenced by the relatively large quantity that was obtained in the few hours devoted to the work, from the small portion of the exposure examined ; and reports of its occurrence elsewhere indicate that careful search, with amber as the object in view, would produce excellent results.

Probably the earliest published record on the subject is contained in an article by G. Troost, entitled : "Description of a Variety of Amber and of a Fossil Substance supposed to be the Nest of an Insect, discovered at Cape Sable, Magothy River, Anne Arundel County, Maryland" (*Am. Journ. Sci.*, vol. 3, 1821, pp. 8–15), in which he describes the amber as occurring with lignite, and says (p. 9) : "This lignite seems to be formed of three varieties of wood, or rather the wood has undergone three different changes, some pieces of which are entirely charred, often changed into bituminous wood, and others again having undergone very little change from the brown lignite. All these varieties, particularly the brown lignite and the charred wood, are penetrated by pyrites, and are sometimes entirely changed into it."

The above account is of considerable interest to us for the reason that the geologic horizon in which the amber was found at Cape Sable is approximately the equivalent of that at Kreischerville, and the conditions under which it occurs at both places are evidently identical. The meaning or significance of the charred wood presents an interesting problem, as it apparently indicates the direct effect of fire, at or immediately prior to the time when the deposits were laid down, and not that of any chemical change such as resulted in the gradual transformation of the wood into lignite. Further than this, its occurrence in such widely separated localities indicates that whatever the source of the heat may have been, the effects were far-reaching and extended over a considerable area. The same author, in the

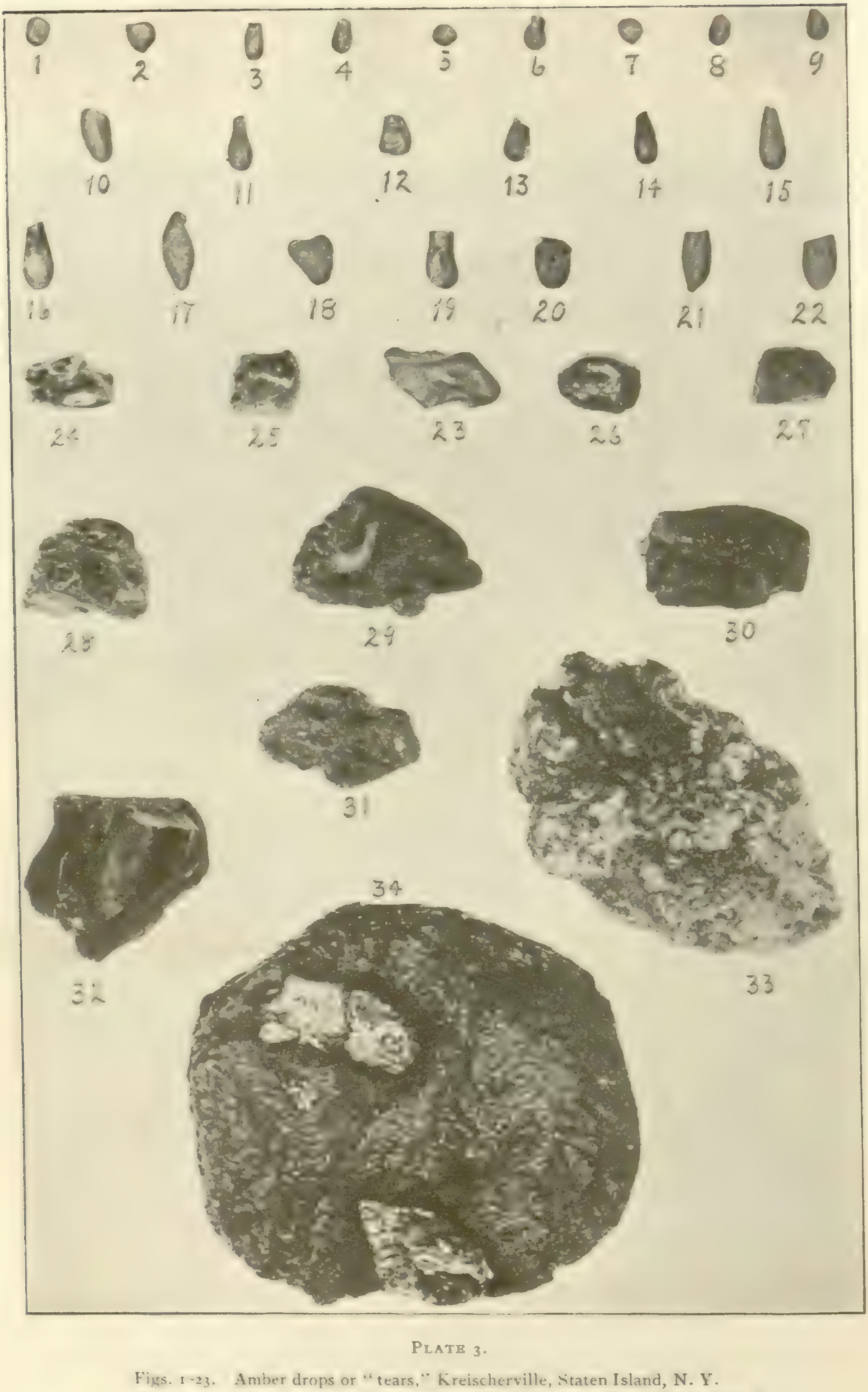


PLATE 3.

Figs. 1-23. Amber drops or "tears," Kreischerville, Staten Island, N. Y.
Figs. 24-33. Amber masses and fragments, Kreischerville, Staten Island, N. Y.
Fig. 34. Matrix containing amber, Kreischerville, Staten Island, N. Y.
(Figures are all natural size.)

article above quoted, also indulges in speculations concerning the kind of wood from which the amber was probably derived, and says (p. 13): "But I have not been able to ascertain the species to which it belongs."

Apparently nothing further was recorded in regard to the subject until 1830, when S. G. Morton published a paper entitled: "Synopsis of the Organic Remains of the Ferruginous Sand Formation of the United States, with Geological Remarks" (*Am. Journ. Sci.*, vol. 17, 1830, pp. 274–295) in which he mentions (p. 293) "vast deposits of lignite with amber," in the sections exposed in cuttings made for the Delaware and Chesapeake canal. Incidental reference to the above may also be found in a subsequent article "On the Analogy which exists between the Marl of New Jersey and the Chalk Formation of Europe" (*Ibid.*, vol. 22, 1832, pp. 90–95).

After this, for a period of some fifty years, our native amber apparently attracted but little attention, or at least there does not seem to have been anything additional recorded in regard to it during that time. A popular article, by Mrs. Erminnie A. Smith, entitled "Concerning Amber," was published in the *American Naturalist*, for March, 1880, in which the only reference in this connection is the following brief paragraph (p. 187): "Very little amber has as yet been found in the United States. Gay Head, Martha's Vineyard, Camden, N. J., and Cape Sable, Md., only are mentioned as its localities. A barrel full of small pieces was taken out of the greensand in New Jersey, which through some mistake was burned."

At a meeting of the New York Academy of Sciences, on February 5th, 1883, Mr. Geo. F. Kunz exhibited a mass of amber ¾ lb. in weight, which was said to have come from the Tertiary deposits of Nantucket, and read a paper "On a large Mass of Cretaceous Amber from Gloucester County, New Jersey," in which was described a mass weighing 64 oz., found in Kirby's marl pit, near Harrisonville (*Trans. N. Y. Acad. Sci.*, vol. 2, 1883, pp. 85–86). In the subsequent discussion of this paper Dr. J. S. Newberry is quoted as remarking that "in one pit [in Gloucester Co.] a whole barrel full had been found and burned by the workmen"; which remark probably has reference to the

incident mentioned in Mrs. Smith's article. In the record of this discussion may also be found a statement, credited to Mr. W. E. Hidden, to the effect that amber had been discovered during the previous summer in the marl beds of North Carolina, and a hearsay reference to a very large specimen from New Jersey, which was "found on the shore of Raritan Bay, and now deposited in the museum at Berlin, Germany."

In 1885 were made the first discoveries of fossil plant remains in the Kreischerville clays (*Proc.* Nat. Sci. Assn. Staten Isld., Dec. 12th, 1885). These were subsequently described by the writer (*Ibid.*, Feb. 13th, 1886) and at the end of the descriptions may be found the following brief paragraph: "There are also little masses of a yellow substance which I take to be a fossil gum or amber." Mr. Wm. T. Davis also found it there subsequently, according to the following record: "Mr. Davis presented unusually fine specimens of lignite, apparently coniferous, from the clay beds of Kreischerville. The specimens were of the appearance and consistency of jet and contained considerable amber," (*Ibid.*, March 12th, 1892). The above mentioned material from Kreischerville was all found in the immediate vicinity of the deposits recently exposed and probably from parts of the same bed.

Probable Origin of the Amber.

In 1894 the Cape Sable locality was visited by Mr. A. Bibbins, who succeeded in finding and collecting a number of specimens of amber, some of which were included in the interstices of a log of lignite and were evidently derived from it. This lignite was examined by Dr. F. H. Knowlton, by whom it was identified as a new species of Cupressinoxylon (*C. bibbinsi*), or in other words the fossil wood of a Sequoia ("American Amber-producing Tree," F. H. Knowlton, *Science*, vol. 3, 1896, pp. 582–584, figs. 1-4). This identification is important for the reason that it gives us definite information, for the first time, in regard to the origin of at least a portion of the amber in this part of the United States, and suggests a probable source for some of that at Kreischerville, where it occurs in close connec-

tion with the leafy twigs of *Sequoia heterophylla* Vel., and *S. reichenbachi* (Gein.) Heer. It may also be of interest to note that leaves of Sequoia are said to be associated with the amber of Japan.

Other coniferous remains which have been found in the Kreischerville clays, and which may have contributed to our supply of amber, are *Widdringtonites reichii* (Ett.) Heer., *Juniperus hypnoides* Heer, *Dammara microlepis* Heer., and Pinus sp. The genus Dammara is prominently represented in our living flora by *D. australis* Lamb, the well known "Kauri" gum tree of Australia. Its former existence, however, as an element in the Cretaceous flora of North America, is somewhat problematic, and is based entirely upon the presence of certain small cone scales, the exact botanical affinities of which have never been satisfactorily determined. The occurrence of remains of the genus Pinus is more significant perhaps than any of the other three last mentioned, by reason of the fact that the typical amber of the Baltic provinces in Europe is recognized as a product of the extinct Tertiary species, *P. succinifera* (Goepp.) Conw.

Acknowledgments.

For answers to letters of inquiry on my part I am indebted to Dr. Lester F. Ward and Dr. F. H. Knowlton of the United States National Museum, Mr. A. Bibbins of the Woman's College of Baltimore, Mr. L. P. Gratacap and Mr. Barnum Brown of the American Museum of Natural History, and to Mr. Geo. F. Kunz, of the United States Geological Survey.

FRESH-WATER RHIZOPODS FROM THE WHITE MOUNTAIN REGION OF NEW HAMPSHIRE.

JOSEPH A. CUSHMAN AND WILLIAM P. HENDERSON.

SINCE the publication of the *Monograph of the Fresh-water Rhizopods of North America*, by Dr. Joseph Leidy, little work has been done upon this very interesting group, especially as regards New England. Their abundance and the singular beauty of some of the species should make them better known even to the most casual observer of the microscopic fauna of our ponds and streams. The number of species obtained from New Hampshire was not great yet when compared with the whole number of shelled forms reported from North America it is a very fair representation. Certain forms found are apparently new and are reserved for further study.

The region from which most of the specimens were obtained was not of great altitude nor of high latitude but nevertheless both of these conditions seem to play an important part in the comparative size of the individuals of the same species. In the summary at the end of the present paper is discussed the bearing of these points as made out from a study of the material under observation.

The material used in the preparation of the present paper was of two kinds: mounted and unmounted. The former is in the collection of the Boston Society of Natural History and represents the following localities: Saco Lake, Profile Lake, Lonesome Lake, Lake of the Clouds, Pinkham Notch, Franconia, Claremont, Gilmore Pond near Profile House, and Scribner's Brook, Wakefield. The unmounted material was preserved in formalin and represents the following localities: Pudding Pond at North Conway; Intervale; a pond at 5000 feet on Mt. Munroe; Mirror Lake in Chatham (all collected by Dr. Glover M. Allen); North Woodstock (including two lots from the Flume, collected by George A. Fisher); Squam Lake (collected by Herman

Gammons); and Mt. Moosilauke (collected by Warren A. Priest). Identified specimens from this latter group of localities are preserved in the collections of the writers and are referred to by slide numbers under each species. For the other localities the number of the slide in the collection of the Boston Society of Natural History which contains an identified specimen is given. Thus all the localities and species may be verified by actual material. A mounted set of material from the second set of localities has been deposited in the collection of the New England Microscopical Society.

The arrangement of the genera and species follows that of Leidy's monograph. The determinations also follow the same work as it is still the standard work of its kind for our species. The following species and varieties were identified: —

Difflugia globulosa Dujardin.

The test of this species showed considerable variation. It was usually of coarse sand grains, but in some specimens included diatom valves, and in a few cases there was a chitinoid membrane with more or less extraneous matter attached to it. Several cases of dividing specimens were noted.

Size.— Length, 46–76 μ; breadth, 40–87 μ; diameter of aperture, 26–45 μ. As noted by Leidy, the specimens having the test composed of coarse sand grains are larger than those with a chitinous test.

Localities.— Mt. Munroe (Cushman Coll., nos. 193, 194); North Woodstock (Henderson Coll., no. 57, Cushman Coll., no. 181); Lake of the Clouds (B. S. N. H., no. 4319); Profile Lake (B. S. N. H., no. 4313); Franconia (B. S. N. H., no. 4307); Saco Lake (B. S. N. H., no. 4324).

Difflugia pyriformis Perty.

Test of coarse angular sand grains, sometimes with included diatom valves. Frequently the outline of the shell was broken by irregularly projecting quartz grains of large size. In a collection from Squam Lake were found several very large speci-

mens, the tests presenting a dark brown appearance. Whether this color was a result of the dark hue of the sand, or arose from a lining membrane of brown chitin in which the grains were incorporated, was not surely made out. One test was unique: trailing from many points in its surface were long blackish streamers, one even longer than the test. Several cases of division were seen.

Size.— Length, 68–309 μ; breadth, 35–201 μ; aperture, 15–87 μ.

Localities.— North Woodstock (Cushman Coll., nos. 183, 187, Henderson Coll., nos. 51, 53, 63); small pond, 5000 ft. alt., Mt. Munroe (Cushman Coll., no. 196); Franconia (B. S. N. H., no. 4307); Pinkham Notch (B. S. N. H., no. 5164); Squam Lake (Cushman Coll., no. 198); Intervale (Cushman Coll., nos. 66, 67).

Of *D. pyriformis* the following varieties described by Leidy, (p. 99) were found: var. *compressa*, North Woodstock; var. *nodosa*, Intervale; var. *vas*, Intervale.

Difflugia urceolata Carter.

Test of the typical form with the urceolate lip. As a rule, however, the lip was not as well marked as in the specimens figured by Leidy.

Size.— Length, 68 μ; breadth, 58 μ; aperture, 30 μ. This specimen is much smaller than that reported by Leidy.

Locality. — North Woodstock (Cushman Coll., no. 176).

Difflugia acuminata Ehrenberg.

Test as a rule of coarse sand grains with the fundus of the test drawn out into more or less of an acuminate projection. This species seems to differ more or less in its comparative breadth as all gradations were noted from very slender to fairly broad specimens.

Size.— Length, 87–125 μ; breadth, 46–60 μ; aperture, 22–31 μ.

Localities.— North Woodstock (Cushman Coll., nos. 182, 189); Intervale (Cushman Coll., no. 152).

Difflugia constricta (Ehrenberg).

Test usually of coarse sand grains; a yellow or brown chitinous membrane with irregularly scattered sand particles noted in one or two cases.

Size. — Length, 80–102 μ; breadth, 59–75 μ; aperture 22–37 μ.

Localities. — Lake of the Clouds (B. S. N. H., no. 4319); Claremont (B. S. N. H., no. 4662); Squam Lake (Cushman Coll., no. 199); North Woodstock (Henderson Coll., no. 62).

Difflugia spiralis Ehrenberg.

Test of varying construction, in one or two cases built up of the vermiform chitinous pellets shown in Leidy's Plate 19, figure 7; in others, of fine, straight, spicule-like fragments. In one, many diatom valves were used. The neck showed much variation in length.

Size. — Length, 44–126 μ; breadth, 38–96 μ; aperture, 12–46 μ.

Localities. — North Woodstock (Cushman Coll., nos. 182, 183, 190); Squam Lake (Cushman Coll., no. 197); Gilmore Pond near Profile House (B. S. N. H., no. 4314).

Hyalosphenia cuneata Stein.

Test of delicate chitinoid membrane, colorless and unornamented.

Size. — Length, 60 μ; breadth, 42 μ; aperture, 24 μ.

Locality. — North Woodstock (Henderson Coll., no. 53).

Hyalosphenia papilio Leidy.

Test a delicate and beautiful case of light straw-colored chitin.

Size. — Length, 111–118 μ; breadth, 67–69 μ; aperture, 31–32 μ.

Localities. — Mt. Munroe (Henderson Coll., no. 102); Mirror Lake, Chatham (Cushman Coll., no. 157).

Hyalosphenia elegans Leidy.

Test of yellowish brown chitin with the characteristic regular longitudinal corrugations. In the specimen examined a peculiar large irregular projection showed near the apex.

Size. — Length, 90 μ; breadth, 58 μ; aperture, 15 μ.

Locality. — Mt. Munroe (Henderson Coll., no. 101).

Quadrula symmetrica (Wallich).

Test as name suggests, composed of a tiling of delicate, unmarked, square, chitinoid plates. These plates increase in size toward the fundus.

Size. — Of specimens viewed on broader side, length, 58–78 μ; breadth, 28–46 μ; oval end, 14–21 μ. One rather larger, but turned so that a slightly oblique view of the narrower side was afforded, gave measurements: length, 87 μ; breadth, 33 μ; aperture, 7 μ. In this specimen the rounding notch of the aperture is visible.

Localities. — North Woodstock (Cushman Coll., no. 181, Henderson Coll., no. 63); Saco Lake (B. S. N. H., nos. 4235, 4325); Franconia (B. S. N. H., no. 4307); Pinkham Notch (B. S. N. H., no. 5148).

Nebela collaris (Ehrenberg).

Test in most of the specimens examined is composed of circular or ovoid plates, transparent and colorless. Several specimens showed straight or curved longitudinal plates mingled with the circular ones. One was bent strongly on one side giving a curved form to the shell.

Size. — Length, 65–196 μ; breadth, 44–108 μ; aperture, 14–46 μ.

Localities. — North Woodstock (Cushman Coll., nos. 176, 178, 180, Henderson Coll., nos. 52, 65); Lake of the Clouds (B. S. N. H., no. 4319); Profile Lake (B. S. N. H., no. 4313); Pinkham Notch (B. S. N. H., no. 5164); Saco Lake (B. S. N. H., nos. 4233, 4323); Mirror Lake, Chatham (Cushman Coll., nos. 156, 157).

Nebela flabellulum Leidy.

Test largely composed of circular disks much as in the preceding.

Size. — Length, 63–90 μ; breadth, 75–100 μ; aperture, 18–20 μ.

Localities. — Lake of the Clouds (B. S. N. H., no. 4319); Scribner's Brook, Wakefield (B. S. N. H., no. 4786); Mt. Moosilauke (Henderson Coll., no. 74).

Arcella vulgaris Ehrenberg.

Test a yellowish or brown chitinoid membrane, with minutely hexagonal cancellation. The common form of the upper surface is an evenly rounded dome, but two or three individuals showed top and sides depressed into bluntly angular facets.

Size. — Length, 42 μ; breadth, 23–54 μ; aperture, 11–15 μ.

Localities. — Mt. Munroe (Cushman Coll., no. 194); Saco Lake (B. S. N. H., nos. 4235, 4323).

Arcella discoides Ehrenberg.

Test of same material as in the preceding, in form more flattened.

Size. — Length, 29–44 μ; breadth, 77–108 μ; aperture, 19–42 μ.

Locality. — North Woodstock (Cushman Coll., nos. 176, 179, 198, Henderson Coll., nos. 54, 64).

Arcella mitrata Leidy.

Test of same material as in the preceding. In form, viewed either from above or from below, with the circular outline broken by the salient angles of the strongly marked facets. In side view, the shell is crown-shaped.

Size. — Length, 63–135 μ; breadth, 67–155 μ; aperture, 34–63 μ.

Localities. — Lake of the Clouds (B. S. N. H., no. 4319); Pudding Pond, North Conway (Henderson Coll., no. 70).

Centropyxis aculeata (Ehrenberg).

Test of yellow or brown chitin as in Arcella. In some of the specimens examined, quartz grains were incorporated in the membrane. The form is always characteristic: mouth and fundus eccentric in opposite directions. The typical form has several spines crowning the fundus.

Size.— Greater diameter, 89–153 μ; shorter diameter, 66–93 μ; aperture, 19–57 μ.

Localities.— North Woodstock (Henderson Coll., nos. 52, 60, 61); Squam Lake (Cushman Coll., no. 197); Pudding Pond, North Conway (Henderson Coll., no. 70); Intervale (Henderson Coll., nos. 66, 69); Gilmore Pond near Profile House (B. S. N. H., no. 4314); Claremont (B. S. N. H., no. 4662).

Centropyxis aculeata var. **ecornis** (Ehrenberg).

As the name implies, the fundus is not crowned with spines. One specimen examined showed the Arcella-like cancellation of the shell noted by Leidy (p. 183).

Size.— Average length, 48 μ; longer diameter, 48–144 μ; aperture, 12–41 μ.

Localities.— North Woodstock (Cushman Coll., no. 176, Henderson Coll., nos. 53, 62); Mt. Munroe (Cushman Coll., nos. 194, 196); Profile Lake (B. S. N. H., no. 4313); Franconia (B. S. N. H., no. 4307); Saco Lake (B. S. N. H., nos. 4325, 4324).

Cyphoderia ampulla (Ehrenberg).

The test in all specimens examined was of similar structure, and varied comparatively little in size. It is a delicate chitinoid membrane, colorless or faintly yellow, showing minute hexagonal cancellation; rim of oval aperture finely beaded.

Size.— Length, 104–143 μ; extreme breadth, 42–50 μ; aperture, 14–18 μ.

Localities.— North Woodstock (Cushman Coll., no. 189, Henderson Coll., nos. 51, 52, 63); Squam Lake (Cushman Coll., no. 198); Lake of the Clouds (B. S. N. H., no. 3719; Profile

Lake (B. S. N. H., no. 4313); Pudding Pond, North Conway (Henderson Coll., no. 71); Claremont (B. S. N. H., no. 4662).

Euglypha alveolata Dujardin.

Test chitinous, transparent and colorless. In form, generally a regular ovoid shape, truncated at the smaller end. One or two specimens were narrower and more flask-shaped. About half of the shells examined had spines.

Size.— Length, 48–91 μ; breadth, 31–46 μ; aperture, 12–18 μ.

Localities.— Profile Lake, Claremont, Franconia, and Saco Lake (B. S. N. H., nos. 4313, 4662, 4307, 4325).

Euglypha ciliata (Ehrenberg).

The plates in the tests of the specimens did not seem to overlap. In one specimen the cilia were few and long, in the others more numerous and shorter.

Size.— Length, 70–78 μ; breadth, 37–42 μ; aperture, 16–18 μ. These were all found in the valley and show little variety in size.

Localities.— North Woodstock (Cushman Coll., nos. 176, 181, Henderson Coll., no. 65); Intervale (Henderson Coll., no. 67); Profile Lake (B. S. N. H., no. 4213).

Trinema enchelys (Ehrenberg).

Closely corresponds to figure 1 of Plate 39 of Leidy.

Size.— Length, 81 μ; breadth, 44 μ; aperture, 16 μ.

Locality.— Franconia (B. S. N. H., no. 4307).

Acanthocystis chætophora Schrank.

But one specimen of this species was found and that was typical in every way.

Size.— Breadth with spines, 125 μ; breadth of body, 54 μ; length of spine, 24 μ.

Locality.— North Woodstock (Cushman Coll., no. 190).

Besides the recording of the species from this general region, one further use was made of this material: a comparison was made with the average measurements of Leidy. The results of this comparison may best be seen in the following table: —

	Lgth.	Bdth.	Aperture.		Lgth.	Bdth.	Aperture.	Leidy-Average. Lgth.	Leidy-Average. Bdth.	Leidy-Average. Aperture.
Difflugia constricta.										
Intervale	178	117	49	Mt. Munroe	68	37	15	320	140	68
Nebela collaris.										
Squam Lake	102	75	37	Lake of the Clouds	80	59	22	161	135	—
Arcella mitrata.										
North Conway	—	155	63	Lake of the Clouds	—	67	34	—	142	50
Centropyxis ecornis.										
North Woodstock	—	83	34	Mt. Munroe	—	59	28	—	146	64

From the above table, which represents the conditions seen in almost all the species under observation, the difference in size between the average measurements of Leidy for the whole of North America and the average measurements for this region is at once apparent. That this is due rather to latitude than altitude it seems safe to infer as the valley lakes are no higher than many of the medium records of Leidy. If it is safe to draw a conclusion from this, it at least seems to indicate that these animals are as a rule smaller in higher latitudes than in lower. Such a conclusion, of course, cannot be of great weight unless worked out in other cases, but is at least indicated here.

The other point which seems much more certain by direct comparisons in this same general locality is that some species are smaller on the tops of the mountains than they are in the valleys of the same region. In the first column are given the measurements of typical valley specimens and in the second column the measurements of specimens of the same species from lakes of about 5000 feet altitude. The differences in this case are at once marked and definite and it may be said with every degree of certainty for the species here worked out that a species at high altitudes will be smaller than the same species in lower altitudes of the same region. This one fact seems to repay the time spent in working up the various lots of material.

CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE. E. L. MARK, DIRECTOR. NO. 162.

THE REACTIONS OF THE POMACE FLY (*DROSOPHILA AMPELOPHILA* LOEW) TO LIGHT, GRAVITY, AND MECHANICAL STIMULATION.

FREDERIC W. CARPENTER.

THE observations which this paper records were made on the movements of the common pomace or little fruit fly, *Drosophila ampelophila* Loew. Insects of this species can be collected in abundance in the autumn, and a culture can easily be maintained in the laboratory all winter if it is kept supplied with decaying fruit such as bananas or apples. The eggs are laid in this material, which later is used by the larvæ as food.

When a large cylindrical glass vessel containing a stock culture of these flies was placed on a table near a window, it was noticed that the flies accumulated in the greatest numbers on the upper part of the side of the vessel nearest the window. This indicated that they were positively phototropic to ordinary daylight, and probably negatively geotropic, although it seemed possible that their position near the top of the vessel might have been due to the fact that, owing to its position near the bottom of the window, the vessel was illuminated more brightly above than below. It was also observed that when the vessel was exposed to direct sunlight the flies, after a time, tended to accumulate, not on the surfaces toward or away from the window, but in intermediate positions on the two sides. Here the majority remained quiet in the regions of least illumination. A similar observation was made by Loeb ('93) on planarians, which

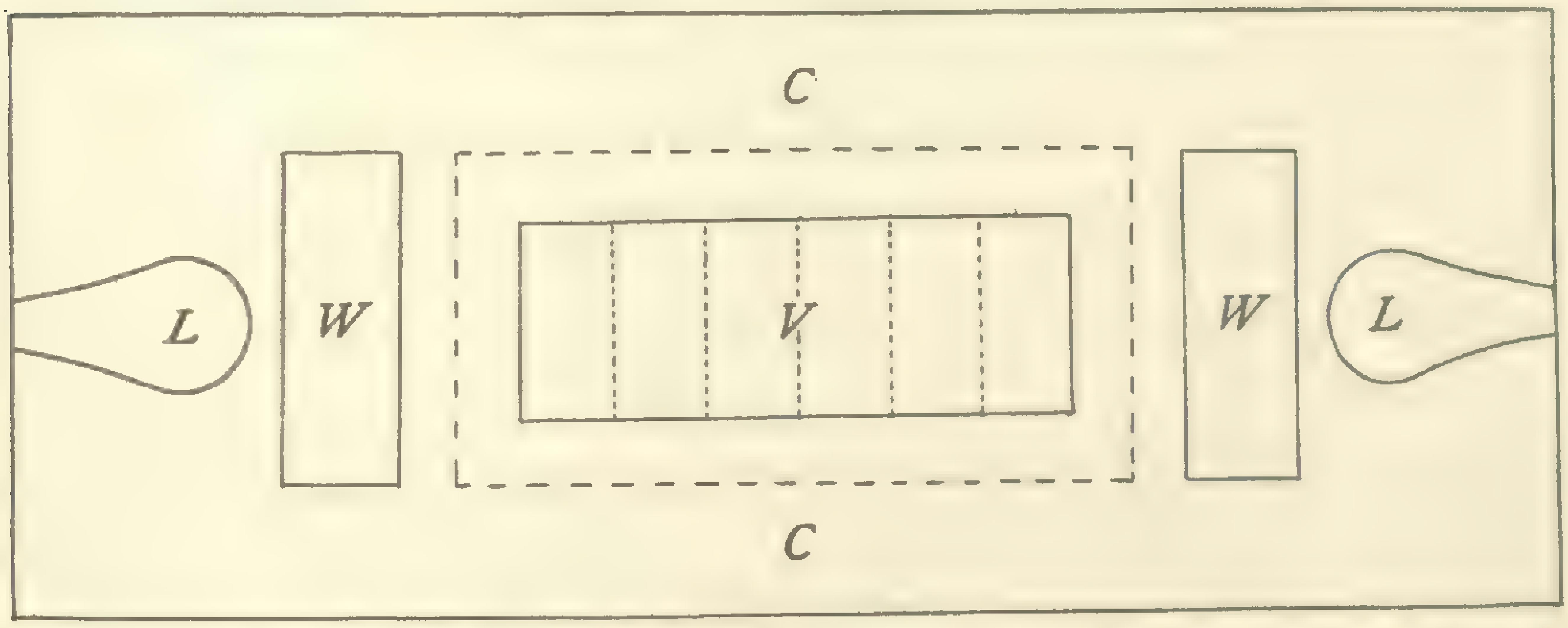
gradually came to rest in the darker portions of a shallow cylindrical glass vessel placed before a window. The large majority of the flies resting thus on the vertical sides of the vessel had their long axes parallel to the light rays, and their heads turned away from the source of light. Parker (:03) has pointed out that the mourning-cloak butterfly, coming to rest in bright sunlight, also places itself with the head away from the sun. The position assumed by the flies under these conditions might have led to the supposition that they had become negatively phototropic through continued exposure to an intensity of light higher than that to which they were accustomed. Such reversals have been observed for barnacle larvæ by Groom und Loeb ('90), for Hydra by Wilson ('91), for Polygordius larvæ by Loeb ('93), for Limax by Frandsen (:01), for copepods by Parker (:02) and for earthworms by Adams (:03). However, it was found that upon slightly turning the vessel on the table nearly every fly flew instantly toward the window, thus giving marked evidence of positive phototropism.

The experiments about to be described were undertaken with a view to obtaining some definite quantitative statements as to the influences of light and gravity on the movements of the organisms; and most particularly was it desired to test the responses of the flies to a range of high intensities of light. For valuable advice and aid in devising the apparatus and conducting the experiments the writer is indebted to Professor G. H. Parker, under whose supervision the work was carried on.

Apparatus.— In all of the operations the flies were confined in a cylindrical glass vessel measuring 15 cm. in length and 5 cm. in diameter, and closed at both ends by glass caps. Around the outside of the vessel were placed five small rubber bands at equal distances apart, the cylinder being thus divided into six sections each 2.5 cm. long. This subdivision of the vessel by surface markings enabled the observer to record the position of the contained fly at any moment with considerable precision.

In some of the experiments a dark box of convenient size was used, a sectional plan of which is given in the accompanying figure. This box was lined throughout with black cloth. In the center of each end wall was fixed an incandescent electric-light

bulb (L.), which projected into the interior. A determination of the amount of light given off from the *ends* of these bulbs showed each to have a candle power of approximately 5. The lighting of both these bulbs could be controlled from the outside by means of keys. A window let into one side of the box gave access to the interior when desired. This window could



Sectional Plan of Dark Box × ½. *C*, dark chamber; *L*, incandescent electric light of 5 c. p.; *V*, cylindrical glass vessel in which flies were contained; length, 15 cm., diameter. 5 cm.; distance of either end of this vessel from light, 7 cm.; the dotted transverse lines indicate the division into six sections by rubber bands; *W*, glass vessel containing water. The broken line surrounding *V* is a projection of the outline of the window of the dark box on the plane of this drawing.

be closed by a tight-fitting shutter. When the dark box was used the glass cylinder (V.), containing the flies, was placed within, midway between the free ends of the two electric-light bulbs, its axis coinciding with the straight line connecting these. The distance from either end of the cylinder to the adjacent electric light filament was 7 cm. Between each bulb and the cylinder was inserted, as a heat screen, a glass vessel (W.), filled with water, and having flat, vertical sides 3 cm. apart. Both the glass cylinder and the heat screens rested on strips of wood painted black; and these supports could be so arranged that the box, with cylinder and heat screens in place, could be used in either a horizontal or a vertical position.

Kinetic Effect of Mechanical Stimulation.—If in ordinary daylight a fly be placed in the glass cylinder, and this be held vertically, the fly will seek the top. If now the vessel be turned upside down the fly, finding itself at the bottom, will creep upward again to the top within considerably less, as a rule, than

one minute. In order to ascertain the behavior, under similar conditions, of flies deprived of light, both when allowed to remain quiet and when mechanically stimulated, the following experiment was undertaken, using the glass cylinder, but not the dark box described above.[1]

Two or three flies, the largest number easily worked with at one time, were put into the cylinder, and while exposed to daylight allowed to pass to its top section, whereupon it was quickly covered in such a way as to exclude all light, and the ends immediately reversed, the section containing the flies being thus made the bottom one. After having been left undisturbed for two minutes the cylinder was uncovered, and the positions of the flies on the sides of the vessel recorded. When they had again reached the top the vessel was placed in the dark again by steps similar to those just described, *viz.*, with the flies in the bottom section. At the end of one minute, however, the whole apparatus was this time revolved on the table top with friction for forty seconds so that the flies were mechanically agitated. Then after twenty seconds of quiet — making in all two minutes in darkness — the cover was removed, and the positions of the flies recorded as before. Periods of quiet in the dark were thus made to alternate with periods involving jarring until five readings for each set of flies had been made. Table I gives the combined records for three females and two males, the figures indicating the number of flies discovered in the sections of the cylinder at the end of two minutes in darkness. Section No. 1 is the uppermost, section No. 6 the lowest.

The table shows that the flies allowed to remain undisturbed were found in 16 instances in the lower half of the cylinder, and in 9 in the upper half, only 2 of these being in the top section; while those flies which were mechanically stimulated were distributed 10 in the lower half and 15 in the upper half, 7 of the latter number being in the top section.

[1] It might be mentioned here that throughout the observations male and female flies showed no consistent differences in their reactions.

Table I.

Distribution of five flies in a vertically placed glass cylinder after two minutes in darkness: the flies at the outset occupied the bottom section of the vessel, No. 6.

Sections of cylinder.	Numbers of trials.					Totals.
	Without mechanical stimulation.					
	1	2	3	4	5	
1		1		1		2
2		1		1	2	4
3		1	2			3
4						0
5	3	1		3		7
6	2	1	3		3	9
	With mechanical stimulation.					
	1	2	3	4	5	
1	1	1	2	3		7
2	2	1	1		2	6
3	1		1			2
4					1	1
5		1			1	2
6	1	2	1	2	1	7

Apparently, then, mechanical stimulation tends to induce the locomotion which results in this upward migration, or, in other words, it has a kinetic effect on the organisms. The direction of the movement indicates a negative response to gravity, a reaction which is more strikingly demonstrated in a succeeding experiment. The lesser degree of activity shown by the flies allowed to remain quietly in the darkness recalls the experiment of Loeb ('90) with plant lice, in which continued confinement in a dark chamber brought on a kind of "dark rigor" ("Dunkelstarre").

Kinetic Effect of Light.— To test the possible kinetic influence of light the following experiment was tried. The glass cylinder, containing a single fly, was placed in a vertical position in the

dark box, with an incandescent electric-light bulb at either end. The lower light only was at first turned on, and the fly thus attracted into the lower section. Then the window of the box was closed, the light turned out, and the fly left for one minute in darkness. At the end of this period both the upper and lower lights were turned on simultaneously, and at the expiration of another minute the window was opened and the position of the fly noted. Five readings were taken in this manner for each of six flies, three males and three females. When the results were combined (see Table II) it was seen that, out of a total of 30 readings, the flies had been detected 19 times in the upper half of the cylinder, no less than 16 of these observations being for the topmost section. In 11 cases the flies had remained below the middle of the cylinder.

Table II.

Distribution of six flies in a vertically placed glass cylinder after one minute's exposure to equal illumination above and below: the flies at the outset occupied the bottom section of the vessel, No. 6.

Sections of cylinder.	Number of trials.					Totals.
	1	2	3	4	5	
1	2	2	5	4	3	16
2	2	0	0	1	0	3
3	0	0	0	0	0	0
4	0	0	0	1	0	1
5	0	1	0	0	0	1
6	2	3	1	0	3	9

When this distribution is compared with that for flies left undisturbed in darkness for an equal length of time (Table I), it would appear that light acts as a stimulant to locomotion; and the rather striking efficiency of light in this respect is attested by the comparatively large number of flies found in the uppermost section of the cylinder.

Directive Effect of Light.— Experiments to demonstrate the directive effect of light of moderate intensity may be thought to

have been scarcely necessary since under natural conditions Drosophila gives such unquestionable evidence of positive phototropism. However, in order to obtain a more detailed expression of this, and to make the observations more complete, the glass cylinder, again containing a single fly, was placed horizontally in the dark box, and the lights on the right and left were alternately turned on and off. By this arrangement the influence of the light was brought to bear on the insect at right angles to the influence of gravity, which could not, therefore, affect the results. The window in the side of the dark box was left open in order that the movements of the fly might be watched. At the beginning of the experiment, when the insect was in the section of the cylinder the farthest to the left, the right light only was turned on. The fly would then creep toward the right along the sides of the cylinder. The time of the excursion from the line bounding the last section on the left to the one bounding the last section on the right was taken with a stop watch. As soon as the fly had crossed the last line on the right, the light at that end of the box was turned off, and the left light turned on. This change in the direction of the illumination was followed by a progression to the left on the part of the fly, an active insect setting out on the return excursion within an average time of about 10 seconds. The progress of the fly toward the left was also timed by the watch. Thus, by reversing the lights, the animal could be made to travel back and forth in accordance with the changes in the direction of the illumination. Flying responses occasionally took place, but, since these were difficult to time, they were not taken into account. Moreover, by neglecting these the records were kept homogeneous in that they were made for creeping excursions only. Individual insects differed considerably in the degree of activity they displayed, and often the same insect would respond less promptly at one time than at another. On those occasions when the kinetic influence of the light seemed for some reason to be partially inhibited, recourse was had to mechanical stimulation to bring the animal into a more active state. This was effected by removing the glass cylinder from the dark box and shaking it. Flies thus treated usually reacted more readily to the light rays for some time after.

In all, four flies, two males and two females, were used in this set of experiments. Each fly was sent five times in each direction. The average time for twenty creeping excursions toward the light from left to right, a distance of 10 cm., was 7.65 sec.; from right to left, 7.71 sec. The average rate in either direction was accordingly about the same, 1.3 cm. per sec. That Drosophila possesses the character of positive phototropism is obvious.

Directive Effect of Gravity.— By arranging the apparatus used in the phototropic experiment just described so that the glass cylinder had a vertical position, it was possible to test the directive effect of gravity on flies stimulated to action by light. The incandescent lamps were now situated one at the upper and one at the lower end of the cylinder, and alternately turned on and off. By means of a stop watch, time records of excursions along the vessel were taken as before. Not all the flies tested responded readily to the light, and preliminary mechanical stimulation produced by shaking the cylinder was sometimes resorted to. Finally two active male insects were found, for each of which five readings were obtained for each direction. The average time for ten creeping excursions toward the light from the bottom to the top of the cylinder through a distance of 10 cm. was 6.2 sec., or at a rate of 1.61 cm. per sec.; from the top to the bottom, 44 sec., or at a rate of 0.23 cm. per sec. The flies crept upward quickly and continuously, and at a rate slightly more rapid than that of flies in the cylinder placed horizontally. In their course downward they frequently stopped for short intervals.

The response to gravity accordingly appears to be a negative one, as was indicated by the behavior of the insects when mechanically stimulated in the dark. In the rapid upward excursions positive phototropism and negative geotropism coincided. In the slow downward ones these two influences were opposed, and although the directive influence of the light proved the stronger, the retarding effect of the opposed influence of gravity was apparent in the strikingly reduced rate of progression.

It happened occasionally that an insect would fly through a

portion of its excursion and alight on the vertical side of the cylinder. When this occurred the fly came to rest with its head uppermost, no matter whether its flight had been directed upward or downward. This orientation of the body on alighting may have been due to negative geotropism.

Effect of Increased Intensities of Light.— In order to subject the flies to light of different intensities use was made of an arc light suspended at one end of a dark room with dead black walls. The glass cylinder containing a single fly was placed horizontally on a small movable table, one end of the cylinder being directed toward the light. The movements of the fly were observed while the end of the cylinder through which the rays fell was at four different distances from the arc light, *viz.*, 800 cm., 300 cm., 80 cm., 40 cm. The candle power of the arc light used was approximately 64. Between the cylinder and the light a rectangular glass vessel containing 3500 cc. of water was interposed as a heat screen. The front and back walls of this vessel were 7 cm. apart.

At each of the four positions the responses of the fly were timed as follows. A small opaque screen was set up between the arc light and the cylinder, and at the opposite end of the cylinder an incandescent lamp was turned on. The fly, attracted by the light of the lamp, crept toward it. At the moment the insect reached the middle of the cylinder the screen obscuring the arc light was removed, the incandescent light extinguished, and the stop watch started. The fly, headed away from the arc light, usually stopped momentarily when suddenly exposed in this manner to the light from behind, and then resuming its course moved on until the opposite (dark) end of the cylinder was reached. Here it turned and hastened toward the illuminated end, either by creeping, or by flying, or by both creeping and flying. With the cylinder close to the arc light the fly sometimes turned about immediately upon the removal of the screen. When the fly crossed the boundary line of the section nearest the arc light the watch was stopped and the time recorded. At distances of 800 and 300 cm. a large majority of the responses were of the creeping kind. At positions nearer the light the insect often flew through a part of the distance —

sometimes through the entire distance. Since it was impossible to obtain pure creeping responses in all cases, those involving both creeping and flying were taken into account. Pure flying responses were not timed.

Observations were made on four flies, two males and two females, and the average time of twenty responses (five for each fly) at each of the four distances from the arc light was obtained. At 800 cm. and 300 cm. and even at 80 cm. the results did not materially differ, the average times of the responses at these three positions being respectively, 18 sec., 18 sec., 16.7 sec. At 40 cm. there was a marked increase in the rapidity of the movements of the flies, the average time of the responses being 7.4 sec.

The behavior of a fly under continued exposure to the highest intensity of light available for these experiments seemed to be of considerable interest. The apparatus used was the same as for the experiments last described, except that an arc light of greater candle power (250 c. p. approx.) was used. The procedure was also unchanged, the insect being brought up from a distance of 300 cm. to 80 cm. and finally to 40 cm. from the light. For each of the first two positions time records for five excursions were obtained, although those for 80 cm. required patient manipulation and many repetitions of the excursions, so numerous did the flying responses become. At 40 cm. the behavior of the fly was such that a full set of five readings could not be taken. Under the influence of the intense light the insect became extremely active, flying and leaping about spasmodically in all directions, and giving little or no evidence of directive responses. That is to say, the directive influence of the light was no longer effective enough to cause the fly to make excursions back and forth along the cylinder in accordance with the position of the illumination. While the fly was in this condition of great muscular activity, the screening off of the arc light and the turning on of the incandescent lamp, were followed by less activity on the part of the animal, but not by a progression toward the illuminated end of the vessel. The directive influence seemed to be for the time inhibited.

It appears, then, that continued exposure to a high intensity

of light produces very rapid locomotor movements, but while the kinetic effect of the light is thus increased, its orienting effect may be strikingly diminished. Throughout the experiments with high intensities there was no evidence of a change from positive to negative phototropism even under the influence of the highest intensity employed, that of a 250 c. p. arc light at a distance of 40 cm.

Discussion of Results.— In the preceding pages it has been found convenient to distinguish between two factors in the effect of light on Drosophila, a kinetic factor and a directive one. These two factors undoubtedly give rise to different kinds of responses, yet they are so closely related that it may be well to lay some stress on their interdependence. The directive effect of light manifests itself only in connection with a kinetic influence sufficient to induce locomotion. The insects while at rest do not regularly lie with their heads directed toward the source of illumination; in fact, those flies of the stock culture already referred to, which, after continued exposure to direct sunlight, came to rest in the least brightly illuminated portions of the vessel, were found with their heads turned away from the window. In the experiments with incandescent lights the turning on of one of the lamps was rarely if ever followed by mere orientation on the part of the fly, *i. e.*, simply an adjustment of the body in such a manner that its long axis became parallel with the light rays and that both eyes received an equal amount of light,— a condition of symmetrical stimulation which Loeb ('97) has maintained to be the essential factor of orientation. While the muscle reflexes necessary to put the insect in this position were usually forthcoming under such stimulation, these movements proved to be initiatory locomotor movements, being continuous with the series of locomotor reflexes which followed. When, on account of light-fatigue or other causes, the insect ceased moving about, no satisfactory evidence of orientation either to light or to gravity could be adduced from the position the animal assumed.

In the case of one fly subjected to the influence of a very high intensity of light, a reaction was obtained which involved only the kinetic factor. This fly while stimulated to great activity

did not appear longer to respond to the directive influence. Its movements were hap-hazard, not guided by the direction of the light, as if the organism, in its state of extreme excitement, had lost for a time its tendency to place itself when in motion under conditions of symmetrical stimulation. This violent kinetic effect of very intense light has been observed for several lower organisms by Pearl and Cole (:02). The conditions of their experiments did not permit them to note the effect on orientation. Long exposure produced a paralyzing effect, so that the movements became more and more slow as the stimulus continued to act. No insects were tested by them.

The experiments with the 64 c. p. arc light made it clear that when the intensity is increased by lessening the distance of the light from 80 cm. to 40 cm. there is a marked increase in the rapidity of true phototropic responses. This result in the case of Drosophila is certainly not due merely to more precise orientation, as was suggested by Davenport ('97) to explain the increase in the rate at which Daphnia traveled under strong light. It is interesting to note that Yerkes (:00), experimenting on the same organism (Daphnia), concluded that while the increase in rate depended chiefly upon precision and quickness of orientation, there was also evidence of a quickening of the swimming motions.

It was stated at the beginning of this paper that when the insects are exposed in a large cylindrical glass vessel, to direct sunlight from a window, many of them eventually come to rest on the sides of the vessel which are least illuminated. Their heads are in this instance directed away from the source of light. When disturbed by the vessel's being turned about they show positive phototropic responses by flying toward the light. This apparent negative orientation while at rest is not due, therefore, to a reversal of the directive influence of the light owing to continued exposure to a higher intensity.

It seems probable that the behavior of the flies under these conditions is the result of the following causes. When first exposed to the strong kinetic influence of bright sunlight Drosophila becomes very active. Its flying and creeping movements toward the light are limited by the wall of the vessel, and the

continued locomotor reflexes bring it into other regions. It may by accident reach the vertical surfaces of the vessel intermediate between the surface nearest and the one farthest from the window. Here the kinetic influence of the light, owing to decreased intensity, is least. The fatigued fly may still, however, be stimulated sufficiently to cause it to creep or at least to turn about. If it chances to place itself with the head directed away from the window, the reduced light stimulus received by the eyes may be inadequate to call forth further muscle reflexes, and the fly remains quiet in this position. Jarring the insect, or turning the vessel about so that more light enters the eyes, may increase the kinetic stimulation to such an extent that renewed movements are induced.

In Drosophila just as light causes locomotion, so mechanical stimulation seems to bring about progressive movements. From the nature of the case this stimulus was very roughly applied in the foregoing experiments, there being no effort to limit its application to one side of the body with a view to detecting its directive effect, if any, under such conditions. On the other hand, an allied form of stimulus, the pull of gravity, directs the movements of the organism, although it does not appear to induce them. A condition of symmetrical stimulation is undoubtedly brought about when, on a vertical surface, the fly places its long axis parallel to the direction of the lines of the earth's attraction. This pull of gravity on the materials which make up the animal's body differs more in degree than in kind from the impact of surrounding objects to which the animal is subjected when mechanical stimulation is applied. If the attraction of gravity and mechanical stimulation are regarded, then, as closely allied forms of stimuli, their two effects upon the organism admit of an almost exact comparison with the two effects of light. When left quietly in darkness, Drosophila gives little evidence of a tendency either to orient itself, or to move about. Thus gravity alone seems insufficient to induce either of these responses. When, however, the insect is mechanically stimulated, locomotor movements do occur, and in connection with them the directive influence of gravity becomes effective. The animal orients itself with its head away from

the center of the earth, and, responding to the kinetic influence of mechanical stimulation, moves upward. The general result is a progression in a definite direction, precisely such as is obtained when a light is placed at one end of a horizontal glass cylinder containing the insect.

Summary of Results.— 1. Mechanical stimulation has a kinetic effect upon Drosophila, since it induces locomotion.

2. Gravity has a directive effect upon the active insect, which is negatively geotropic, that is, the insect moves away from the center of the earth.

3. Light has both a kinetic and a directive effect. The insect moves toward the source of light, being positively phototropic. The directive effect is apparent only when the kinetic stimulus is sufficient to induce locomotion.

4. The exposure of Drosophila to light of high intensity is accompanied by an increase in the kinetic effect. Under the influence of the highest intensity used, that of a 250 c. p. arc light at 40 cm., the muscle reflexes of an insect become very rapid and violent, and the directive influence of the light seems inhibited. There is no indication of a reversal of the directive influence from positive to negative.

5. After continued exposure to direct sunlight in a large cylindrical glass vessel many insects come to rest in the least brightly illuminated regions and with their heads away from the source of light. This is not an indication of negative phototropism. The fatigued insects remain quiet in this position because it is the one in which the least light enters the eyes, and in which, as a consequence, the kinetic stimulus is least.

BIBLIOGRAPHY.

ADAMS, G. P.

:03. On the Negative and Positive Phototropism of the Earthworm Allolobophora fœtida (Sav.) as determined by Light of Different Intensities. *Amer. Jour. Physiol.*, vol. 9, no. 1, pp. 26–34.

DAVENPORT, C. B.

'97. Experimental Morphology. Part First: Effects of Chemical and Physical Agents upon Protoplasm. New York, xiv + 280 pp.

FRANDSEN, P.

:01. Studies on the Reaction of Limax maximus to Directive Stimuli. *Proc. Amer. Acad. Arts and Sci.*, vol. 37, pp. 185–227.

GROOM, T. T., und LOEB, J.

'90. Der Heliotropismus der Nauplien von Balanus perforatus und die periodischen Tiefenwanderungen pelagischer Tiere. *Biol. Centralb.*, Bd. 10, No. 5–6, pp. 160–177.

LOEB, J.

'90. Der Heliotropismus der Thiere und seine Uebereinstimmung mit dem Heliotropismus der Pflanzen. Würzburg, 118 pp.

LOEB, J.

'93. Ueber künstliche Umwandlung positiv heliotropischer Thiere in negativ heliotropische und umgekehrt. *Arch. f. ges. Physiol.*, Bd. 54, Heft 1–2, pp. 81-107.

LOEB, J.

'97. Zur Theorie der physiologischen Licht- und Schwerkraftwirkungen. *Arch. f. ges. Physiol.*, Bd. 66, Heft 9–10, pp. 439–466.

PARKER, G. H.

:02. The Reactions of Copepods to Various Stimuli and the Bearing of this on Daily Depth Migrations. *Bull. U. S. Fish Comm. for 1901*, pp. 103–123.

PARKER, G. H.

:03. The Phototropism of the Mourning-cloak Butterfly. Vanessa antiopa Linn. *Mark Anniversary Volume*, pp. 453–469, pl. 33.

PEARL, R., and COLE, L. J.

:02. The Effect of very Intense Light on Organisms. *Report Mich. Acad. Sci. for 1901*, pp. 77–78.

WILSON, E. B.

'91. The Heliotropism of Hydra. *Amer. Nat.*, vol. 25, no. 293, pp. 413–433.

YERKES, R. M.

:00. Reactions of Entomostraca to Stimulation by Light. II. Reactions of Daphnia and Cypris. *Amer. Jour. Physiol.*, vol. 4, no. 8, pp. 405–422.

NOTES AND LITERATURE.

GENERAL BIOLOGY.

Le Dantec's Treatise on Biology.[1] — The author of this considerable volume is well known from a number of general treatises of a popular nature all characterized by an agreeable style, but written rather freely, not to say speculatively; that is, not based at every step on ascertained fact. His works are what we are accustomed to think of as typically French, as opposed to the typically German treatises that build up a science out of numberless bricks of recorded observations (all fully referred to bibliographically) laid down in orderly fashion.

Le Dantec's volume is readable but not epoch-making. In places it introduces the reader to the very latest ideas — as in the suggestive chapter (V) on The Generation with Chromosomes and Sexual Parasitism. In other places it seems to bring us back to an earlier age, as in the discussion of the formation of species — species being defined as groups whose hybrids are sterile.

The author treats of many things, as a glance at the Table of Contents shows: chemical activity in a liquid plasm; assimilation; chemical and histological complexity; sexuality; sexual parasitism; heredity; acquired characters; amphimixis; the determination of somatic sex; life and death; the formation of species; histological differentiation of Metazoa; parallelism of psychology and physiology; and, lastly, "la liberté et l'égalité" among animals.

The book is clearly written and will be read by many interested in semispeculative biology based, for the most part, on recent knowledge; but considering its lack of bibliographic citations and its somewhat glib treatment of difficult subjects it cannot be considered indispensable to the worker.

C. B. D.

Organic Evolution.[2] — The author states in his preface that this

[1] Le Dantec, Felix. *Traité de Biologie.* Paris. Alcan, 1903. 8vo, 553 pp. 101 figs. in text. 15 francs.

[2] Metcalf, M. M. *An Outline of the Theory of Organic Evolution, with a Description of some of the Phenomena which it explains.* New York. Macmillan Co., 1904. 8vo, xxii + 204 pp., 143 pls., and 46 text-figs.

book "is not intended for biologists, but rather for those who would like a brief introductory outline of this important phase of biological theory." Nevertheless it will doubtless prove a very useful work in the hands of beginners in biology and of the "nature-study" teacher, and is sure to be attractive to the general reader because of the wealth of illustrative material which it contains. This material has been selected with great care and forms an integral part of the work. It is one of the best of the popular treatises on evolution.

W. E. C.

BOTANY.

Plant-Breeding.[1] — This useful and deservedly popular handbook, originally published in 1895, now appears in a third edition, revised so as to cover the important period since 1900, when Mendel's law was rediscovered. The work meets the needs of a wide circle of readers, including the general public particularly interested at the present time in the subject of horticulture, the practical plant-breeder, and the student. To the student the extensive bibliography appended to the book will be especially valuable.

W. E. C.

Haberlandt's Physiological Anatomy of Plants.[2]— It is now twenty years since the first edition of this work appeared and despite the mass of new material which has accumulated in that time, the author is able to adhere to his original plan in the exposition of the structures and functions of plant tissues. There is, indeed, not so much difference between this third edition and the second published in 1896, as there was between the last named and the first imprint of 1884. Nevertheless there is a considerable amount of new material, as is shown by the fact that the number of pages has increased from 550 to 616, and that the illustrations number 29 more in the new edition.

[1] Bailey, L. H. *Plant-breeding, being five Lectures upon the Amelioration of Domestic Plants.* New York. Macmillan Co., 1904. 16mo, 3d edition. xiii + 334 pp., frontispiece and 20 text-figs.

[2] Haberlandt, G. *Physiologische Pflanzenanatomie.* Leipzig. Engelmann, 1904. 8vo, 3rd edition. xvi + 616 pp., 264 figs. in text.

It is near the end of the book that the greatest change is to be noticed. In place of the eleventh chapter on tissues for special functions, we find the subject augmented to three chapters as follows: tissues for movement, sense organs, and tissues for conducting stimuli. In the first is an account of the passive hygroscopic movements of certain plant parts, and of the active movement, as seen in pulvini, stamens, etc. In the second is an elaborate treatment of the statolith theory, as well as descriptions of various forms of sensitive hairs and papillæ. In the third part the writer considers the propagation of stimulus in Mimosa, and in his explanation adheres to his former point of view. Here also he gives an account of *inter*- and *intra*-cellular conduction of stimuli.

Haberlandt's treatment of anatomy well deserves the prefix physiological, and stands, as it is intended to, in striking contrast to the mere topographical anatomy of many other writers. Any hard and fast system must naturally have a narrowing influence and a too ready acceptance of all the classifications of tissues and interpretations of functions in Haberlandt's book would no doubt lead the reader into the sloughs of teleology. We can however make what reservations we wish in his causal explanations and still have left a wonderfully suggestive and stimulating analysis of the aspects of plant tissues, viewed from a functional standpoint. That the author may at times carry this idea of the purposeful development of tissues too far, cannot be denied, yet even this is better than a purely formal treatment of the subject from a regional standpoint only. At least there is impressed upon the reader that plant tissues have functions, and that these functions constitute a real interest in the study of anatomy. In these days of increased interest in physiological problems and of the advance in knowledge of physiological processes, such a book as this will come more and more into consideration. The physiologist and ecologist, whether or no they always agree with the author, must frequently have occasion to consult the book and it may be suggested that the topographical and phylogenetic anatomist would do well to pay greater attention to Haberlandt's point of view.

There is one thing omitted from the book which should perhaps have found place, namely, a closing chapter by way of a general summing up of the inter-relations of the various "systems," so that a more complete picture of the plant as a whole might be obtained. The section of half-a-dozen pages in the first chapter, in which the physiological efficiency of the tissues is treated, does not fill the

want, which could best be supplied at the end, after all the types of tissues had been taken up. Possibly the author has purposely left the reader to construct for himself this picture of the plant as a whole.

The appearance of a book as valuable as this in a foreign language, always brings with it a certain regret when there is no similar work available in English. Excellent as it is, the translation of DeBary's anatomy is now very far behind the times and there is no other detailed account of plant anatomy in our language. In common with many others we hope that a translation of this third edition of Haberlandt's work will not be long in forthcoming.

H. M. R.

British Fresh-water Algæ.[1] — In his treatise on the British Fresh-water Algæ, G. S. West gives a general view of this group, based largely upon his own studies of the British Algæ. The great changes that have been made in recent years and the consequent limiting of the usefulness of previous monographs is noted. The need of a monograph of the fresh-water Algæ which may be used to determine the genera and species is also called to one's attention. The book contains many new facts concerning life histories, development, and relationships of the Algæ. It is illustrated by a large number of text-figures most of which are original and the localities from which the specimens were taken are noted. The Peridineæ and Characeæ are left out as not being certainly true Algæ. Besides a short preface, there is an introduction in which, after disposing of the historical considerations, the author discusses the occurrence, collection, preservation, and cultivation of the Algæ. Another chapter is devoted to a brief consideration of the six classes of the fresh-water Algæ, their vegetative, asexual and sexual reproduction, polymorphism; and the remainder of the chapter is given over to a discussion of the phylogeny and classification, which is based on the latest work on the various groups. The main portion of the book deals with the various classes, orders, and families, with a full description of each genus. As a rule each genus is illustrated, often by more than one species. Under each genus are brief notes and accurate measurements of the British species most frequently met with. The work recognizes the law of priority in dealing with the names of the genera, thus tending to fix in general use certain older but much less generally used names.

J. A. C.

[1] West, G. S. *British Fresh-water Algæ.* Cambridge Biol. Series, Cambridge Univ. Press, 1904. 8vo, xv + 373 pp., 166 figs. in text. 10/6.

British Desmidiaceæ.[1] — There has lately appeared the first volume of the *Monograph of the British Desmidiaceæ* by W. West and G. S. West. This is the third monograph that has been written on British desmids. The first was by Ralfs, in 1848, the second by Cooke, in 1887, the latter being mainly a compilation. Since the publication of Cook's work there have been 400 species and 402 varieties added to the desmid flora of Great Britain. The present volume is prefaced by a brief historical account. A very full bibliography takes up the twenty pages preceding the introduction. In the introduction a very complete general account of the family is given, especial attention being paid to the cytological characters. A number of pages are devoted to the discussion of the following points: variation, locomotion, vegetative, asexual and sexual reproduction, phylogenetic relationships, occurrence and distribution, collection and preservation, examination and specific determination. A diagrammatic table is given showing the phylogeny as worked out by the junior author a few years ago. The arrangement of the genera follows this scheme and an analytical key is given to all the genera recognized on this basis. This includes thirty-one genera, five of which have not been found in the British Isles. The remainder of the volume is given up to the systematic treatment of twelve genera, concluding with Tetmemorus. Under each species or varietal name appear the following points: a short synonymy, brief diagnosis including the zygospore, when known, and the range of measurements, the British localities grouped under England, Wales, Scotland, and Ireland, the geographical distribution as far as known, followed usually by certain critical remarks. As a rule the tendency seems to be to reduce the number of species and varieties instead of to increase, as is usually the tendency. One new species, *Mesotænium truncatum*, and several new varieties are described. The volume is illustrated by thirty-two plates, containing about six hundred figures, of which most are original and many are colored.

J. A. C.

[1] West, W., and West, G. S. *Monograph of the British Desmidiaceæ*, Vol. I. London, Ray Society, 1904. 8vo, xxxvi + 224 pp., 32 pls.

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IN THEIR WIDEST SENSE

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BIRDS OF THE ISLE OF PINES.

OUTRAM BANGS AND W. R. ZAPPEY.

Introduction.

The following account of the birds of the Isle of Pines is, for the most part, based on a large collection and field notes made by one of us (Zappey) in the spring and early summer of 1904. Zappey had, however, visited the island once before — in March, 1902 — and the few birds, mostly North American migrants, taken on that trip that were not observed on the later one, are included.[1] In addition to this material, William Palmer and J. H. Riley, who spent two weeks in July, 1900, near Nueva Gerona, have most kindly placed in our hands their notes and lists of birds observed and taken. And lastly, in order to make our list complete, we include such species as were recorded from the island by Poey, by Cory, and by Gundlach.

Mr. Riley has made many comparisons for us with the material in the United States National Museum, and has otherwise done everything in his power to help us, and we here express our most hearty thanks for all his kindness.

[1] This first collection, unfortunately, did not remain in this country but went to the Tring Museum, and thus far has not been reported upon.

Literature.

While no very complete list of the birds of the Isle of Pines has been published, many references to the ornis of the island can be found in the writings of Poey, Cory, and Gundlach,

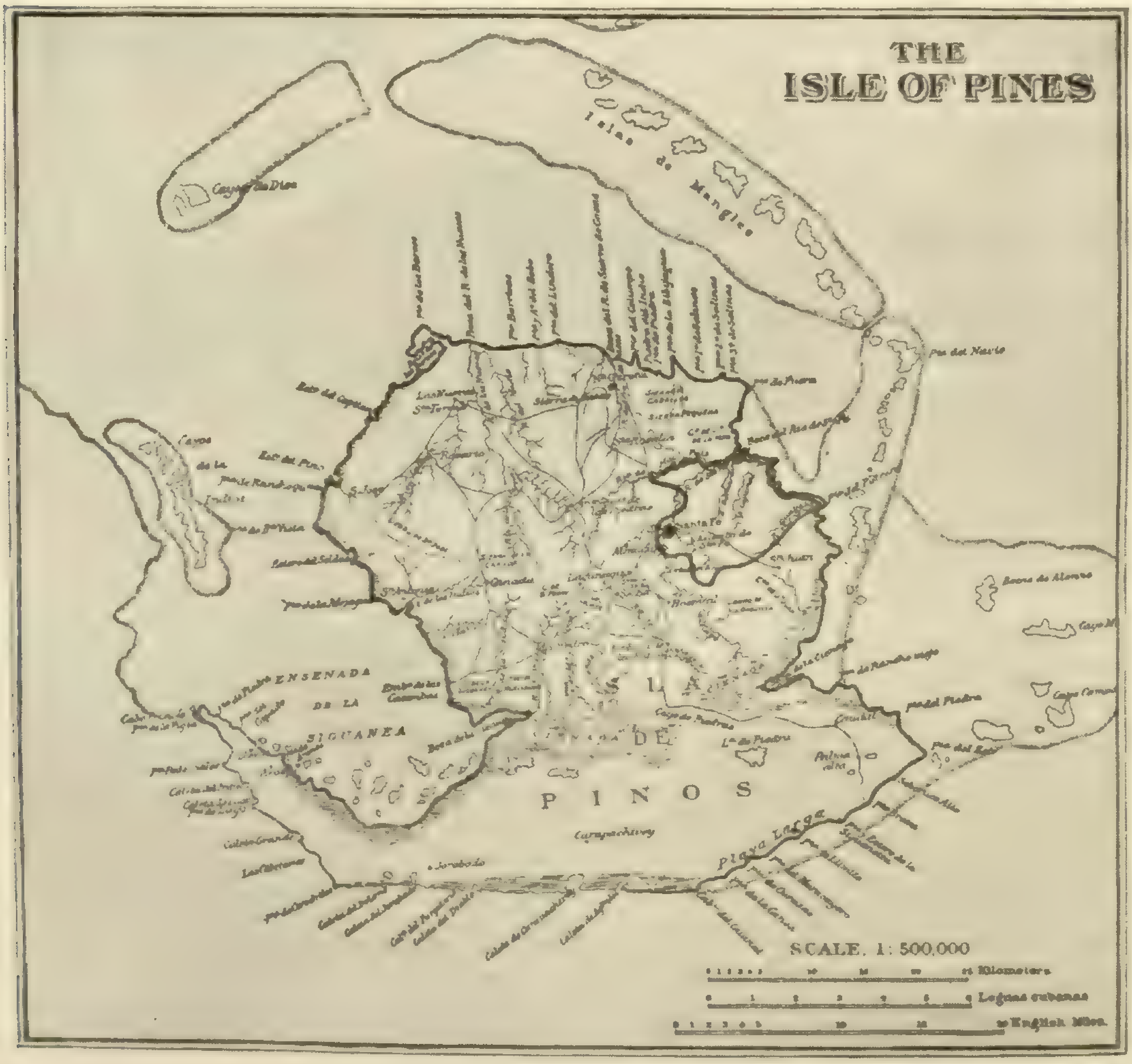

Fig. 1.— Map of the Isle of Pines.

and in the three parts that have already been issued of Ridgway's *Birds of North and Middle America*. The full references to these works are as follows: —

Felipe Poey, *Memorias sobre la Historia Natural de la Isla de Cuba*, 1854.

(Tomo 1, pp. 426–427: a nominal list of birds observed by Gundlach during a six days' stay at Nueva Gerona.)

C. B. Cory, *Catalogue of West Indian Birds*, 1892.

(Numerous references to the birds of the Isle of Pines, probably from MSS. furnished the author by Gundlach. The Isle of Pines appears in the distribution of the various species, usually as Greater Antilles, No. 2.)

Juan Gundlach, *Ornithologia Cubana*, 1895.

(The last work of this distinguished Cuban ornithologist, containing many references to the birds of the Isle of Pines.)

Robert Ridgway, *The Birds of North and Middle America.* Bulletin of the United States National Museum, No. 50. Part I, 1901; Part II, 1902; Part III, 1904.

(Each species known to the author to occur on the Isle of Pines, is recorded from there, and in one or two instances measurements are given for comparison and critical remarks made, as for example in the case of the Spindalis.)

FIG. 2.— Isle of Pines, as seen from the northeast. The rocky islet in the foreground was the roosting place of hundreds of Cormorants and a few White Ibises.

PHYSICAL ASPECT OF THE ISLE OF PINES AND CLIMATE.

The Isle of Pines lies about 60 miles south of Cuba, and can be reached by rail from Havana to Batabano and thence by sailing vessel or steamer to the island.

The Isle of Pines is about 30 by 40 miles in extent, containing some 1240 square miles, or a trifle less than the State of Rhode Island. It is divided into two parts, the northern one

being the larger, by a fresh-water swamp, the "Cienaga," that runs across the island from east to west.

The land south of the Cienaga is of coral formation with a very shallow soil spread over the coral rock, and with deep holes or pits everywhere. A number of prints of fossil shells of various kinds were observed in the coral rock. Fires devastate this part of the island, burning up the soil and the very roots of the trees and leaving nothing behind but the bare coral rock, and the region is very sparsely inhabited. The trees of this region are mostly hard wood, there being no pine and very few royal palms.

North of the Cienaga, the country is of a very different char-

FIG. 3.—Casas River, Caballos Mountains in the distance. Mangrove bushes in the foreground along the river, and as the land rises, dense palmetto scrub.

acter. There are here a number of mountains rising abruptly from the plain, Pico de la Dacuilla, the highest, having an altitude of about 2000 feet. The flat country is diversified by pastures, cultivated fields, open pine woods, and groves of royal palms and palmettos and along the water courses there are dense tropical forests. The mountain sides are very rocky and are clothed chiefly with scrub and thorn bushes and, where there is soil enough, some good-sized trees. The banks of the rivers and

many parts of the shore of the island are fringed with mangroves which give way as the land rises, to a dense growth of palmetto.

In the Isle of Pines the rainy season begins in the early part of May, and rain falls continually until October. The character of the country is entirely changed. The Cienaga is covered by two or three feet of water and the rivers, which are nearly dry in the dry season, become torrents.

Great difficulty was experienced in taking photographs especially after the rain began, but the accompanying views selected from a great many, give some idea of the general character of the island.

Birds.

About eighty-three species of birds, most of them resident, breed in the Isle of Pines.[1] Besides these, a few northern species either winter there or make a short stop in spring or autumn, but the list of migrants thus far is not a long one.

Owing to its nearness to Cuba and to the fact that, geologically speaking, its separation from that island was recent, one would not look for any marked peculiarities in the birds of the Isle of Pines, and such do not exist. Nevertheless many of the birds of the island have already become slightly changed and although they strictly represent the Cuban species, it seems best to give some of them distinctive names. The changes that have thus far taken place are chiefly in size and proportions, colors in most of the species remaining the same or very similar. There is no rule in these changes in size,— some of the birds of the Isle of Pines are larger, others are smaller than their Cuban representatives.

All the birds of the island are well known by the natives, who have a name for nearly every species. In the following list we give these names. In some cases we may be slightly in error in the spelling of them as it is impossible to find a native who can write them correctly.

[1] This number includes some species probably now extinct and a few larger birds — such as the Frigate Bird and Flamingo — that may or may not actually breed in the island.

Some species that were seen and not taken by either Zappey or Palmer and Riley, but were probably correctly identified, we give with a question mark. It would be a pity to leave these out of a list of the birds of the island and yet there must ever be a doubt about such records, and this seems to us the best way to treat such cases. A few species, also included in the following list, rest solely on Poey's authority (based on a list furnished him by Gundlach).

Following is a list of the birds[1] of the Isle of Pines, with

FIG. 4.—Country back of the town of Nueva Gerona. Casas Mountains in the distance.

notes on their habits, distribution, etc., and with critical remarks, and descriptions of a few new forms, drawn from the various sources enumerated above.

1. **Podilymbus podiceps** (Linn.).— An adult female and three downy young were found by Palmer and Riley in a small lake near Nueva Gerona. One of the young was taken but the old bird was very wary and could not be secured.

[1] The systematic sequence of this list is about the same as that followed by Ridgway in the *Birds of North and Middle America*, now appearing in parts, based principally upon Hans Gadow's *A Classification of Vertebrata, Recent and Extinct*, 1898, only turned about so as to bring the "lower" (less specialized) orders first. Colors are according to Ridgway's *Nomenclature*, and measurements are in millimeters.

Two were shot by Zappey, and one of them saved, in March, 1902, at Laguna Grande, but in the spring of 1904 no Pied-billed Grebes were observed anywhere in the island.

2. **Phalacrocorax dilophus floridanus** (Aud.). "CORNA" — Cormorants were common along the seacoasts of the island and among the outlying cays, and undoubtedly all birds inhabiting the salt water belong to this form, which has been recorded from Isle of Pines by Cory and by Gundlach. Specimens of the Florida Cormorant were secured by Palmer and Riley on the Cuban coasts, and many were observed at Batabano opposite the Isle of Pines.

3. **Phalacrocorax vigua mexicana** (Brandt). "CORNA." — One young adult female, was taken in the Cienaga at Pasadita in May. This was the only one observed.

This specimen is rather larger than usual for *mexicana*, but E. W. Nelson who has compared it for us with the large series collected by himself in Mexico, says that it is equalled and even exceeded by some Mexican individuals, and authors generally have considered the Cuban Fresh-water Cormorant to belong to this race rather than true *vigua*.

The skin, no. 13,236, measures: wing, 268; tail, 164; tarsus, 50; exposed culmen, 50.

4. **Anhinga anhinga** (Linn.). "CORNA REÁL." — The Anhinga was found by Zappey in the Cienaga only, where it was fairly common and a number might be seen any day sitting on dead branches of trees in different parts of the swamp, with wings and tail extended to the rays of the sun. One was seen by Palmer and Riley at Nueva Gerona.

Two specimens — a fine pair of adults — taken by Zappey, May 28, 1904, do not differ in any way from Florida birds.

5. **Fregata aquila** Linn. "RABIHORCADO." — Occurs occasionally off the south coast of the island, and during a severe storm was seen high in air passing over the town of Santa Fé. Palmer and Riley also saw it at Managua.

6. **Pelecanus fuscus** Linn. "ALCATRAZ." — A few individuals were seen on the south, but none on the north coast.

7. **Pelecanus erythrorhynchos** Gmel. — The White Pelican has been recorded by Cory from Isle of Pines. None were

observed by Palmer and Riley nor by Zappey on either trip. It is probably a very irregular winter visitor to the island.

8. **Ardea repens** sp. nov.

Type from the Cienaga, Isle of Pines, adult ♀, no. 13,241, Coll. of E. A. and O. Bangs. Collected May 24, 1904, by W. R. Zappey.

Characters. — Similar to *Ardea occidentalis* Aud. of south Florida but very much smaller.

Color. — Entirely pure white; the bill yellow; legs and feet greenish yellow.

Measurements. — Type: wing, 440; tail, 156; tarsus, 172; exposed culmen, 144.

Since the ornis of Cuba has first been known, up to the present time, references to *Ardea occidentalis* can be found in the literature, but specimens do not appear to have been taken. Birds from Cuba and the Isle of Pines are in all probability the same, and certainly cannot be referred to *A. occidentalis*, being far too small. This is all that can be said at present. Future research may prove this bird to be the white phase of the Great Blue Heron of Cuba, but here again there appear to be no specimens, and it is not known to what form that bird belongs. Under the circumstances we have thought it best to give the white bird a name as it certainly is not *A. occidentalis*.

Zappey saw this bird but once — the one taken. Palmer and Riley observed a few about the cays.

9. **Ardea herodias** Linn. (*sub. sp. ?*). — The Great Blue Heron was seen on several occasions in the Cienaga, but was very shy and none were secured. A few were also seen by Palmer and Riley about the cays.

As stated under the preceding species, it is still unknown to what form the Great Blue Heron of Cuba and the Isle of Pines belongs, and possibly it may be the colored phase of the bird we describe as *Ardea repens*.

10. **Herodias egretta** (Wilson). "Garcilate." — A few Egrets were seen, in different parts of the island, both inland and on the seacoast, always singly, and they were very shy.

In former years it was abundant, but has been nearly extirpated for its plumes.

A fine adult female was taken at La Vega, May 22, 1904, and one was obtained by Palmer and Riley at Nueva Gerona.

11. **Florida cærulea cærulescens** (Latham). "Garga Azul." — Very common, being found both on the seacoasts and in the Cienaga.

Two specimens, ♂ and ♀, were taken respectively at Guanawana, May 15, and in the Cienaga, May 23.

12. **Leucophoyx candidissima** (Gmel.). "Garga Blanca."

Fig. 5.— Palmetto and royal palms near the Casas Mountains.

— The Snowy Heron is now very rare in the Isle of Pines, having been killed off for its plumes. One was seen in the Cienaga, and at Jucaro a native had a wounded bird that was kept alive in confinement.

13. **Hydranassa tricolor ruficollis** (Gosse). "Garga." — This species is not uncommon in the seacoast lagoons and the brackish water of the rivers, but was only once seen in the Cienaga.

One female was taken in the Cienaga, May 23, 1904.

14. **Nyctanassa violacea** (Linn.). "Guanaba."—Recorded from Isle of Pines by Poey, Cory, and Gundlach. None were seen by Zappey nor by Palmer and Riley.

15. **Nycticorax nycticorax nævius** (Bodd.). — In March, 1902, a flock of Black-crowned Night Herons was seen at a fresh-water lagoon in the northern part of the island and two others in a salt lagoon at Bibeyhagua. It is also recorded from the island by Poey.

16. **Butorides virescens maculata** (Bodd.). "Aquaita." — The Green Heron occurs, in small numbers, wherever there is fresh water, and was also occasionally seen along the seacoast.

As has been pointed out by Riley, all West Indian Green Herons are much alike, and must be called by Boddært's name. The form differs from true *virescens* of the mainland chiefly in being smaller.

Two males were taken : one at Bibeyhagua, May 15, the other at Santa Fé, April 20.

17. **Butorides brunnescens** (Lembeye). — Two specimens of this dark-colored bird were taken by Palmer and Riley near Nueva Gerona.

We cannot avoid a strong impression, despite its peculiar coloration and the fact that young individuals are as different as adults from *B. virescens maculata*, that this supposed species is a color phase of the ordinary bird. This, however, can be proved by careful observation only, by ascertaining whether the two breed together or mate each with its own kind only.

18. **Ardetta exilis** (Gmel.). — The Least Bittern was abundant in the Cienaga in March, 1902. On the 1904 trip, made later in the spring, none were found anywhere, leading to the conclusion that those seen in March were winter residents and that the bird does not breed in the Isle of Pines.

19. **Botaurus lentiginosus** (Montag.). — Recorded by Cory and Gundlach from the Isle of Pines, but not observed by Zappey nor by Palmer and Riley.

20. **Eudocimus albus** (Linn.). "Coco." — One of the commonest and most characteristic birds of the Cienaga, flocks

of from forty to fifty being often seen. It also occurs though not in such large numbers in most parts of the island. It feeds on snails, frogs, and lizards. The natives often tame the White Ibis and it then runs about with the domestic fowl and eats table scraps and the like, which it always carries to the nearest water and soaks before swallowing. These tame birds were also very fond of the bodies of small birds that had been skinned, and would catch them when thrown to them, before they touched the ground.

One specimen was taken, a male, at Pasadita, May 8.

21. **Ajaia ajaia** (Linn.). "CERVEIA." — The natives claim that a few Roseate Spoonbills still occur in the Isle of Pines. The species is recorded by Poey and formerly was not uncommon. It was not seen by Zappey nor by Palmer and Riley.

22. **Tantalus loculator** Linn.— Recorded from the Isle of Pines by Cory. Its occurrence there is probably only casual as it was not found by Zappey nor by Palmer and Riley.

23. **Phœnicopterus ruber** Linn. "FLAMENCO."— A few Flamingoes inhabit Punta del Este and Bibeyhagua. None were seen alive, but one morning the tracks of about a dozen were found in the mud, and on another occasion three individuals that had just been shot by a native were examined.

24. **Chen hyperborea nivalis** (Forst.).— An occasional winter visitor, recorded from the island by Cory and by Gundlach.

25. **Dendrocygna arborea** (Linn.). "LLAGWASA." — The Whistling Duck occurs in considerable numbers in the Isle of Pines. During the day it keeps concealed in the Cienaga but in the evening, toward dusk, it leaves the swamp to feed in the royal palms, alighting on the trees and picking off the berries. One night a half a dozen or so alighted in the palms in the plaza at Santa Fé. The call note of this bird is much like that of the Wood Duck (*Aix sponsa*).

Six specimens, adults of both sexes, were taken in the Cienaga in May.

26. **Querquedula discors** (Linn.). — In March, 1902, the Blue-winged Teal was in the Cienaga in considerable numbers. On the second trip none were found, the species probably leaving for the north before the middle of April.

27. **Cathartes aura aura** (Linn.). "AURA."— The Turkey Buzzard is very common everywhere in the island. The bird of the Isle of Pines, and other West Indian Islands, is very much smaller than that occurring in the southern United States and

FIG. 6.— Palmetto growth bordering the pine lands. The highest tree in the center of the picture, is a species of pine that grows chiefly near the seacoast north of the Cienaga.

as Wied named the latter *septentrionalis*, Linné's name should be restricted to the small southern form, since he gave the distribution of his *Vultur aura* as North America, Jamaica, Mexico, etc. The Turkey Buzzard of the southern United States should be known as *Cathartes aura septentrionalis* (Wied).[1]

[1] *Cathartes septentrionalis* Wied, *Journ. f. Orn.*, p. 119, 1856.

Two specimens, ♂ and ♀, were taken at Santa Fé and measure as follows: —

No.	Sex.	Wing.	Tail.	Tarsus.	Culmen.
13,376	♀	483	236	69	38
13,377	♂	456	228	69	41

28. **Polyborus cheriway** (Jacq.). "CARAIRA." — This is not a common bird in the Isle of Pines and is extremely shy. Whenever there happens to be a dead animal anywhere, however, one or two Caracaras will always be found near by. They also feed on lizards and are said by the natives to kill small chickens.

One male was taken at Santa Fé, May 20. This specimen does not differ from skins from Florida and elsewhere on the continent.

29. **Urubitinga anthracina** (Licht.). "BATISTA." — The Cuban Crab-hawk is recorded from the Isle of Pines by Poey, as *Hypomorphus gundlachi* Cab.

There are no specimens available to us for comparison of the Cuban bird, and we are therefore forced to follow the general custom of placing it under true *U. anthracina*.

The species was not detected in the island by Zappey nor by Palmer and Riley.

30. **Rostrhamus sociabilis** (Vieill.). "CARBRETO." — Common in the Cienaga and also seen at Santa Rosalia lagoon. Its food consists of small snails, though the natives assert that it eats frogs and lizards also.

One male taken at the Cienaga, May 23, is in every way like specimens from Florida.

31. **Falco peregrinus anatum** (Bonap.). "HALCÓN." — One was examined in March, 1902, that had struck and killed a hen, and being either unable or unwilling to let go, was chopped to pieces by some natives with their machetes.

32. **Falco columbarius columbarius** Linn. — Recorded from the Isle of Pines by Cory and by Gundlach as an occasional winter visitor.

33. **Cerchneis sparveria dominicensis** (Gmel.). "CERNICALO." — Very common everywhere in the island. This form has the same habit as the Sparrow Hawk of Florida, of congre-

gating in numbers wherever the brush or grass has been set on fire and hovering just in front of the flames. In the Isle of Pines they appear to get small lizards only in this way, there being no small mammals.

Seven specimens were taken at Santa Fé, San Juan, Jucaro, Laguna Grande, and Almacigos, in April and May. Of the great number seen, one only was in the dark phase of plumage, and Palmer and Riley state that *all* observed by them were in the white-bellied plumage.

34. **Pandion haliaetus carolinensis** (Gmel.).— Recorded from the Isle of Pines by Cory; not observed by Zappey nor by Palmer and Riley.

35. **Colinus cubanensis** (Gould). "CODORUIZ." — The Cuban Quail was common in the pastures and fields about Santa Fé and Nueva Gerona, where they were nesting in May.

Three males were taken at Santa Fé and Callebonita in May; these specimens do not differ in any way from Cuban examples.[1]

36. ? **Rallus elegans** Aud. "GALLINUELA." — In March, 1902, a large rail was rather common in the Cienaga, and several specimens were taken. None could be found on the later trip and the bird apparently does not breed in the island. (The skins taken on the first trip are in the Tring Museum, but Zappey is sure they were referable to the King Rail.)

37. **Gallinula galeata** Bonap. "GALLINETA." — In March, 1902, a few individuals were found in Santa Rosalia lagoon. None were met with on the later trip and it is probable that the gallinule does not breed in the island. Recorded from the Isle of Pines by Cory.

38. **Ionornis martinica** (Linn.). "GALLINUELA." — The Purple Gallinule breeds abundantly in the Cienaga but was not noted anywhere else in the island.

Four males were taken in the Cienaga at Pasadita, in May and June. These specimens are slightly larger than examples from the mainland of the southern United States, measuring as follows: —

[1] The Guinea Fowl (*Numida meleagris* Linn.), and the Domestic Hen (*Gallus* sp.?), have both run wild in the Isle of Pines, and are occasionally found throughout the island, apparently perfectly naturalized.

No.	Sex.	Wing.	Tail.	Tarsus.	Bill.[1]
13,232	♂ ad.	182	70	59	31
13,233	♂ ad.	183	79.5	63.5	30
13,234	♂ ad.	190	75	59	30.5
13,235	♂ ad.	179	69	61.5	31

39. **Fulica americana** Gmel.— Recorded from Isle of Pines by Cory and by Gundlach. Not noted by Zappey nor by Palmer and Riley. As with many other species that are winter residents in the Isle of Pines, the trips made by Zappey and by Palmer and Riley were too late in the season to find these birds still in the island.

40. **Grus nesiotes** sp. nov.[2]

" GRULLA."

Type from La Vega, Isle of Pines, adult ♂, no. 13,238, Coll. of E. A. and O. Bangs. Collected May 8, 1904, by W. R. Zappey.

Characters.— Similar to the Sandhill Crane of Florida, (usually called *Grus mexicana* Müll.) in color, but slightly darker and not so clear a gray on back; smaller with shorter tarsus; beak somewhat stouter and heavier.

Measurements: [3] —

No.	Sex.	Locality.	Wing.	Tail.	Tarsus.	Culmen.
13,238	♂ ad.	Isle of Pines, La Vega	474	187	209	125
13,239	♂ ad.	Isle of Pines, Pasadita	460	171	204	123

[1] Measured from a point in line with eye and nostril to tip.

[2] This bird may or may not be considered different enough from the Sandhill Crane of North America to rank as a full species; we have given it a binomial because we fully agree with Dr. Sharpe that the bird called *Ardea* (*Grus*) *mexicana* by P. L. S. Müller is not the one to which the name is generally applied — the Sandhill Crane of North America. Until the synonymy of these birds is properly adjusted it is better not to give the Isle of Pines Crane as a subspecies.

[3] For comparison with these, specimens from the United States measure as follows: —

No.	Sex.	Locality.	Wing.	Tail.	Tarsus.	Culmen.
684	♂ ad.	Wisconsin	508	202	230	135
691	♂ young.	N. Dak., Harrisburg	518	187	224	124
10,717	♂ ad.	Fla., Micco	514	192	238	125
10,718	♂ ad.	" "	494	195	248	132
4107	♂ ad.	Fla., Henderson Camp	470	170	223	128
4106	♀ ad.	" " "	444	159	217	122
10,716	♀ ad.	Fla., Haines City	465	188	247	136

The Sandhill Crane is rare and of local distribution in the Isle of Pines, and was only met with in the high, open country just north of the Cienaga, where it usually occurred in pairs, though on one occasion a flock of six was seen. When disturbed, it utters a loud honking or gobbling call note not unlike some of the sounds produced by the Domestic Turkey. The birds seen were always exceedingly shy, and the two specimens were secured with a good deal of difficulty.

On May 20, a small downy young individual was found running about alone. It was exactly the color of the soil. It was kept alive for a day or two but would not eat anything given it. The skin is that of a young not long hatched. It is covered with down which is tawny along the back, tawny-ochraceous on sides, and whitish on throat and middle of belly.

After careful comparison of a large series of North American Sandhill Cranes, we feel fairly sure that the birds still breeding in Florida are not different from those that breed in North Dakota and other parts of the west. Probably in former years the breeding range was continuous or nearly so, and it is due to the interference of man that the Florida bird is now isolated.

In the breeding season the Sandhill Crane is much browner, — losing most of the pearly gray of the back and neck, — than in fresh autumn plumage, and this is true of birds both from the west and from Florida. Unfortunately, however, we have seen *only* breeding birds and birds killed in early spring from Florida, and therefore no gray ones, but we have no doubt that fresh autumnal specimens from Florida would be quite as gray as those from the west. In measurements there is no difference.

The bird of the Isle of Pines, and almost certainly Cuba also, differs from that of the continent in its decidedly shorter tarsus, heavier bill, and slightly smaller size. In color the difference is slight, but still our two Isle of Pines skins are rather darker and browner than any breeding Florida birds with which we have been able to compare them.

41. **Aramus giganteus holostictus** (Cab.).[1] "GUARACAO."

[1] *Notherodius holostictus* Cabanis, *Journ. f. Orn.*, p. 426, 1856, based on Cuban specimens.

— The Limpkin was found in the Cienaga only, where it was far from common, and where one adult male was taken in May.

This specimen is smaller, with shorter tarsus, and much shorter and smaller bill, than any in a large series of Florida birds with which we have compared it. It is also paler in general coloration; the tail is lustrous olive brown (dark, lustrous purple in true *A. giganteus*) and the white markings on wings, wing-coverts and scapulars are smaller. The skin, no. 13,237, ♂ ad., measures: wing, 308; tail, 138; tarsus, 114; exposed culmen, 110.

We have therefore thought it best to recognize the Cuban and Isle of Pines birds as a subspecies.

42. ? **Ochthodromus wilsonius rufinucha** (Ridg.). "Frailecillo." — A few birds, undoubtedly belonging to this form, were seen along the shore at Plaza Larga, but none were secured.

43. **Oxyechus vociferus torquatus** (Linn.).[1] "Frailecillo." — A few pairs of Killdeer breed in the Isle of Pines. They were seen on several occasions, and a young in the down was caught, but let go again at the beach at Bibeyhagua.

One adult male was taken April 21, at Laguna Grande, and Palmer and Riley took specimens at Nueva Gerona.

The breeding Killdeer of the Greater Antilles is a good deal smaller than the bird of continental North America and should be recognized as a subspecies.

Our specimen, ♂ ad., no. 13,335, measures: wing, 146; tail, 82.5; tarsus, 34; exposed culmen, 21.

The larger Killdeer of the north winters in many of the islands, and this fact must be borne in mind in identifying specimens, else confusion is sure to ensue. There is no trouble in distinguishing the two forms, however, when breeding birds are compared.

44. **Himantopus mexicanus** (Müll.). "Zarapico Reál." — Two Black-necked Stilts, one of which, an adult female, was taken, were found in the Salina at Bibeyhagua, May 15. The

[1] *Charadrius torquatus* Linn., *Syst. Nat.*, vol. 1, p. 255, 1766, based on *Pluvialis dominicensis torquata* Briss., Aves, vol. 5, p. 70, pl. VI, fig. 2, from Santo Domingo.

species is probably of very casual occurrence anywhere in the West Indies.

45. **Catoptrophorus**[1] **semipalmata semipalmata** (Gmel.). "Zarapico Reál."— No Willets were met with by Zappey nor by Palmer and Riley. It is recorded from the Isle of Pines by Poey.

46. **Totanus melanoleucus** (Gmel.). "Zarapico Reál."— One specimen, an adult female, was taken at the Salina at Bibeyhagua, May 15.

47. **Totanus flavipes** (Gmel.).— In March, 1902, specimens of the Summer Yellowlegs were taken, but none were observed on the last trip to the island.

48. **Helodromas solitarius solitarius** (Wils.). "Zarapico."— One adult female was taken May 11, at Jucaro; it was in a little puddle at the roadside left by a heavy shower.

49. **Actitis macularia** (Linn.). — Spotted Sandpipers were not uncommon about the shores of the island in March, 1902. None were seen on the last trip.

50. **Asarcia spinosa** (Linn.). "Gallito."— The Jaçana occurs in every fresh-water lagoon, but is most abundant in Santa Rosalia lagoon and the Cienaga.

When disturbed it stretches up its wings and runs along over the lily-pads and weeds for a short distance before taking flight, at the same time uttering a loud alarm note that sets all others in the vicinity to flying.

Three specimens were taken at Laguna Grande and Pasadita, in April and May.

51. **Sterna maxima** Bodd. "Gaviota."— The Royal Tern was common along the seacoasts of the island and on the mangrove cays. Several were shot, but fell into the ocean and before they could be retrieved, were gobbled up by sharks.

52. **Columba inornata** Vig. "Palonea Babo," "Torcaza."— One specimen of this pigeon was taken in March, 1902. It was not met with at all on the second trip and is said by the natives to be very rare in the Isle of Pines. It is among the species given from the island by Poey.

[1] *Cf.* Richmond, *Proc. Biol. Soc. Washington*, vol. 18, p. 75, Feb. 21, 1905.

53. **Columba leucocephala** Linn. "Torcaza Cabeza-blanca."— The White-crowned Pigeon is not uncommon along the river courses, especially where there are royal palms, upon the fruit of which it feeds.

Two specimens, both males, were taken at La Vega in April.

54. **Columba squamosa** Bonn.— Palmer and Riley inform us that this species occurs in the vicinity of Nueva Gerona but is rare there.

55. **Zenaidura macroura bella** Palmer and Riley. "Paloma."— Throughout the island in the open pine woods, palmetto groves, and especially in old fields grown up to weeds, the Cuban Mourning Dove is an abundant bird. Several nests were found in low trees five or six feet from the ground.

Three specimens, two males and a female, were taken at Rio Santiago and Hospital in May. These are similar in every way to Cuban examples.

56. **Zenaida zenaida zenaida** (Bonap.). "Paloma."— The Zenaida Dove inhabits the same sort of country as the last species, the two being found together, but it is not so abundant.

Two specimens, both males, were taken at Almacigos, April 19.

57. **Columbigallina passerina aflavida** Palmer and Riley. "Tojosita."— Common everywhere in the island except in the denser woods. Several nests were found placed on the ground, containing two eggs each.

Seven specimens, of both sexes, were secured at Callebonita, Hospital, Jucaro, and San Juan, in May. These do not differ at all from Cuban specimens.

58. **Geotrygon montana** (Linn.). "Boyero."— The Ruddy Quail-dove occurs in the Isle of Pines in the denser woods only, usually in rather moist places, where the ground is often flooded after heavy rains. It is nowhere abundant. When flushed from the ground it flies but a short distance and on alighting again runs along for a few feet and conceals itself among the vegetation much after the manner of the American Woodcock (*Philohela minor*), which it curiously resembles when started in the deep woods.

Six specimens, including both sexes, were taken at La Vega, Pasadita, and Callebonita in May and June.

These skins are not to be distinguished in any way from skins from Jamaica, the type locality of the species.

59. **Geotrygon chrysia** (Bonap.). "CANIÁO."— The Key

FIG. 7.— Callebonita River before the rainy season when the water was very low. "Guana blanco" palms in the foreground.

West Quail-dove is very rare in the Isle of Pines occurring only on one or two of the mountains and in the dense forest south of the Cienaga.

Only two individuals were seen. These were both secured, at Pasadita, one in May the other in June.

60. **Starnœnas cyanocephala** (Linn.). "Perdiz."—This bird has not been actually seen by any naturalist in the Isle of Pines. We include it because the natives who know it well positively assert that a few inhabit the Caballos Mountains and some point near the south coast.

61. **Saurothera merlini decolor** subsp. nov.

"Arriero."

Type from La Vega, Isle of Pines, adult ♂, no. 13,246, Coll. of E. A. and O. Bangs. Collected April 24, 1904, by W. R. Zappey.

Characters. — Somewhat similar to true *S. merlini* d'Orb. of Cuba, but smaller, with decidedly shorter bill; much paler in color, wholly lacking the hazel or pale chestnut suffusion of back, head, and rump, these parts being, in the new form, uniform dull hair-brown; the ferruginous color of the lower underparts also much paler and duller and more restricted, never reaching the lower breast. In general coloration the Isle of Pines bird — except for the chestnut patch in the wing — more nearly resembles *S. bahamensis* than *S. merlini merlini*.

The young is like the adult except that it lacks the black subterminal band to the rectrices.

Iris brown, bare skin around eye scarlet, legs slate blue (from fresh specimen just killed).

Measurements: —

No.	Sex.	Wing.	Tail.	Tarsus.	Culmen.
13,246	♂ ad.	163	267	42.5	52.5
13,247	♂ ad.	161	262	43	55
13,243	♂ ad.	164	235	43	52
13,242	♂ ad.	158	255	41.5	51.5
13,244	♀ ad.	149	226	39.5	50
13,245	♀ ad.	161	252	40.5	54

The Lizard Cuckoo of the Isle of Pines is a common bird in rough, rocky country wherever there is a thick growth of scrub and bushes, and is very tame. It has a habit of hopping from one branch to another till it reaches the top of a bush and then sailing down to the ground or the lower branches of another

bush. Its usual call note is a sort of laugh that begins low and slowly, and rapidly ascending, ends in a loud chuckle. When two individuals are within sight of each other they often go through a curious performance, which consists in lowering the head and dropping the feathers of the throat which then looks like a large pouch, at the same time spreading the wings and tail to their fullest extent and repeating the loud chuckling notes that end the usual call. The stomachs of those taken contained the remains of small lizards, beetles, caterpillars, and large moths.

Seven specimens were taken, adults of both sexes and one young, at La Vega, Callebonita, and Hospital, in April, May, and June.

The Isle of Pines Saurothera is a very well marked form differing much from true *S. merlini* of Cuba in size and proportions as well as in its paler and plainer coloration, and perhaps should be considered a distinct species. We, however, prefer to treat representative island forms as subspecies, unless they present even more strongly marked characters than do these two cuckoos. By so doing, the affinities of a bird are seen at a glance by its name, whereas, by the use of binomials they are lost.

62. **Crotophaga ani** Linn. "Judio." — The Ani is a common bird in the Isle of Pines, occurring in all pastures, in brushy regions, and along the river courses. It was often seen on the backs of horses, cattle, and hogs picking off ticks.

Five specimens were taken at Callebonita, Santa Fé, and Jucaro, in April and May.

63. **Ara tricolor** (Bechst.). "Guaeamáyo." — It has been supposed that perhaps the Cuban Macaw still lingered in the Isle of Pines. Unfortunately this is not so. The last pair known in the island was shot at La Vega, near the Cienaga, about the year 1864, and none have been seen since. This information was furnished by the man on whose plantation they were shot.

64. **Conurus euops** (Wagler). "Periquito." — Formerly abundant in the Isle of Pines, the paraquet has been nearly if not quite exterminated in very recent years. Nothing was seen of it and the natives all said that none now occur in the island.

65. **Amazona leucocephala** (Linn.). "Cotorra." — The parrot is still common in the central part of the island, but is rare south of the Cienaga — a few pairs only being seen in some royal palms at Pasadita.

In May, the parrots were breeding. The nests usually contained young though several were examined in which there were eggs, four in number, of a whitish color. The nesting site is invariably an old woodpecker's hole in the trunk of a species of palm that has a large swelling about midway up. The parrot feeds largely in the pines, eating the ends of the new shoots that are soft and green.

Hundreds of young birds are taken annually by the natives and sent alive to the United States. The exporting of live parrots being the chief industry of the island, nearly every nest on the island is found and robbed every year, and although the natives do not kill the old birds and dislike very much to have them shot, nevertheless the parrot is steadily decreasing in numbers year by year, and must inevitably go the way of the macaw and the paraquet unless some steps are taken to protect it.

One adult male was taken at Hospital, May 12. This does not appear to differ in any way from Cuban examples.

66. **Todus multicolor** Gould. "Podorera." — Along the river courses and dry gulches, where there is a thick growth of brush, the little Tody is frequently met with sitting upright on a branch from which it occasionally darts to catch some insect on the wing, its wings as it does so making a loud whirring sound.

Its call note is a curious sound much like that produced by hitting two small stones together.

Eleven specimens, adults of both sexes, were taken at Santa Fé and Callebonita in April and May, and are quite the same as Cuban examples.

67. **Ceryle alcyon** (Linn.). "Martin Zambullidor." — The Belted Kingfisher is a regular winter visitor to the Isle of Pines. In March, 1902, it was not uncommon, but on the last trip none were seen, all having probably left for the north.

68. **Nyctalops stygius siguapa** (d'Orb.).[1] "Siguapa." —

[1] *Otus siguapa* d'Orb., in Ramon de la Sagra's *Histoire de l'Isle de Cuba, Oiseaux*, p. 40, pl. 2, 1839. Based on Cuban specimens.

The Cuban Eared Owl inhabits in the Isle of Pines the heaviest and densest forests only. It is very rare, and being wholly nocturnal is extremely hard to obtain.

One fine adult male was taken at La Vega, May 25. This specimen compared with three continental examples,— one each from Brazil, Mexico, and Guatemala — differs in being less buffy both above and below, the under parts are much whiter, and the facial disk is white. It is probable that the Cuban bird is the same, and the island race named by d'Orbigny seems a perfectly valid one.

69. **Gymnasio lawrencei** (Scl. and Salv.). "Cotunto." — This queer, long-legged little owl, with much the general appearance of a Burrowing Owl is strictly nocturnal, spending the day in hollow trees. A pair taken at Santa Seville, May 31, had with them a brood of three half-grown young in a hole in a tree. These young birds were kept alive for a time and were then given to a native, who like so many of his countrymen was very fond of taming and keeping birds in confinement.

Three specimens, two adult males and an adult female, were taken at Pasadita and Santa Seville, in May. These skins compared with a series of six from Cuba show a slight difference in color, being paler with less of a brownish or rufous cast than the Cuban specimens. In measurements they do not differ, and the slight color difference may or may not hold in larger series from the two islands.

70. **Glaucidium siju** (d'Orb.). "Siju."— One of the characteristic bird-sounds of the island, with which one soon becomes very familiar, is the cry of this little owl. Though the bird is diurnal, its call is often heard at night as well as by day. It is generally distributed throughout the island and is very common.

The stomachs of those taken contained nothing but insects, beetles of various kinds forming the greater part of the contents.

Six specimens, adults of both sexes, were taken at Santa Fé and Callebonita in April, May, and June. These are indistinguishable from Cuban specimens.

71. **Strix pratincola furcata** (Temm.). "Lechuza." — The Barn Owl is not at all common in the Isle of Pines. But two were seen and two others heard at night.

One adult female was taken at Santa Seville. It had been eating a Ruddy Quail-dove (*Geotrygon montana*).

72. **Chordeiles virginianus virginianus** (Gmel.). — Probably an irregular migrant, though it is recorded from Cuba by Cory.

On May 10, a male was flushed from the ground and alighted in a pine, at Santa Fé, where it was shot. This specimen measures: wing, 200; tail, 105; tarsus, 14; culmen, 8. It is in every way like birds that breed in New England.

73. **Chordeiles virginianus minor** (Cab.). "Cericaday." — Common everywhere in the island in the more open country and among the pines. In rainy weather it was often seen flying during the day, and at other times roosting lengthwise on a pine limb.

Five specimens were taken at Almacigos, Santa Fé, and Hospital, in April and May.

Chordeiles virginianus minor like many other species of birds of somewhat similar general coloration, appears to be dichromatic, having a rusty and a gray phase of plumage, regardless of sex, age, or season. In the present series all are in the rusty phase of plumage except one female that is very gray. In a series from Cuba we find both phases — one male from Holquin, May 31, being quite the color of Florida specimens of *C. virginianus chapmani*. That it is not that form can of course be told by its smaller dimensions.

74. ? **Antrostomus vociferus** (Wilson).— Recorded from the Isle of Pines with a query by Poey. We consider this an extremely doubtful record probably applying to the next species.

75. **Antrostomus cubanensis** Lawr. "Guaraiba." — A bird of this species was started from the ground in the dense woods south of the Cienaga in June, and was shot, but was so mangled that it could not be saved. It was the only one seen.

76. ? **Hemiprocna zonaris pallidifrons** (Hartert).— Palmer and Riley saw about the crest of the mountain at Nueva Gerona some large swifts, that they felt confident belonged to this form.

77. **Riccordia ricordii** (Gerv.). "Zung Zung."— The hummingbird is rather generally distributed throughout the island,

though nowhere abundant. Several nests were found containing two eggs each. It is a noisy little bird and its mouse-like, squeaking note is uttered at frequent intervals, especially when anything attracts its attention.

Four specimens, adults of both sexes, were taken at Almacigos and Santa Fé, in April, May, and June.

78. **Prionotelus temnurus vescus** subsp. nov.

"TOCORORO."

Type from Almacigos, Isle of Pines, adult ♂, no. 13,250, Coll. of E. A. and O. Bangs. Collected April 19, 1904, by W. R. Zappey.

Characters. — Similar to true *P. temnurus* (Temm.), of Cuba in color-pattern and probably in color also. (The Isle of Pines series was taken in spring and early summer, and all Cuban specimens with which we have been able to compare them, in winter, except one. The red belly-patch in the Isle of Pines specimens is much paler and more pinkish — less geranium red — than in the Cuban skins, but the one summer specimen from Cuba is like them in this respect and this difference in the color of the belly-patch is probably due to fading). Much smaller with much shorter tail; in the new form the wing averages 114.11, the tail 107.55; in true *P. temnurus* the wing averages, 123.41, the tail 119.41.

Iris bright carmine, lower mandible red (from fresh specimen before skinning).

Measurements : —

No.	Sex.	Wing.	Tail.[1]	Tarsus.	Culmen.
13,250	♂ ad.	113.5	104	18	19.5
13,251	♂ ad.	115	104	18	19
13,254	♂ ad.	114	106	17.5	19.5
13,255	♂ ad.	113	110	18.5	18.5
13,258	♂ ad.	114	108	18.5	18.5
13,252	♀ ad.	115	107	18	19
13,253	♀ ad.	113	108	17.5	18.5
13,256	♀ ad.	115.5	113	17.5	18
13,257	♀ ad.	114	108	17	18.5

[1] In every instance the tail is measured to the end of the longest *shaft*, not the end of the projecting webs.

For comparison with these a series from Cuba measures as follows : —

No.	Sex.	Locality.	Wing.	Tail.	Tarsus.	Culmen.
14,927	♂ ad.	Cuba, Halquin	124	118	19	19
14,928	♂ ad.	" "	123	118	18.5	17.5
14,925	♂ ad.	" "	123.5	120.5	18	18.5
14,926	♀ ad.	" "	121	117	18	18
11,976	♂ ad.	Cuba, El Guama	124	120	18	20
11,975	♀ ad.	Cuba, San Diego de los Baños	125	123	19	18.5

The Trogon is rather common in the dense woods and along

Fig 8.— Cienaga, at Pasadita, a short time after the rains had begun. (The birds held up are Sandhill Crane and the White Ibis.)

the river courses. It is a stupid sluggish bird and very tame. Its food consists of fruits of various kinds.

Nine specimens, adults of both sexes, were taken at Puebla Nuevo, Almacigos, Pasadita, and Callebonita, in April and May. These are so very much smaller than Cuban examples that we have thought it best to separate the Isle of Pines bird as a sub-

species, though its smaller size seems to be the only character by which it can be distinguished.

79. **Melanerpes superciliaris** (Temm.). "Carpintero." — An extremely abundant and very noisy bird, found over nearly all the island.

Eight specimens, adults of both sexes and two young, were taken at San Juan, Jucaro, Nueva Gerona, and Almacigos, in April, May, and June. These skins run slightly smaller than Cuban ones and have less of the olivaceous tinge below and slightly less red on the belly. All of these characters, however, are rather inconstant and the form though slightly different is not enough so to be regarded as a subspecies.

The young — a male and a female taken June 4 — differ from the adults in having the feathers of the breast, belly, and back tipped with dull scarlet; the scarlet of head duller, more orange; the female has scarlet tips to the feathers of the middle of the crown and differs from the male, only in having the frontal band wider and dull gray instead of white.

The skins measure as follows: —

No.	Sex.	Wing.	Tail.	Tarsus.	Culmen.
13,262	♂ ad.	134	90	27.5	37.5
13,261	♂ ad.	140	92	28	40
13,259	♂ ad.	134	91	26	38.5
13,260	♂ ad.	134.5	91.5	26.5	36.5
13,263	♀ ad.	133	95	26	36
13,264	♀ ad.	130	85 much worn	26	35.5

80. **Sphyrapicus varius varius** (Linn.). — A migrant or winter visitor in the Isle of Pines, first recorded by Poey. In March, 1902, several individuals were seen, but none were noted on the last trip, as it was too late in the season.

81. **Xiphidiopicus percussus** (Temm.). "Carpintero Reál." — The Green Woodpecker is common in the Isle of Pines and generally distributed, and its low grating croak soon becomes a familiar sound.

Eight specimens, adults of both sexes, were taken at Santa Fé, Callebonita, and Jucaro, in April and May. These are not to be distinguished from Cuban specimens.

82. **Pitangus caudifasciatus** (d'Orb.). "Pitirre." — A

not uncommon species along the river courses but always found near water. One nest was found in a palmetto close to the trunk about eight feet from the ground.

Nine specimens were taken at Santa Fé, Hospital, Jucaro, and Callebonita River, in April, May, and June.

83. **Blacicus caribæus** (d'Orb.). "BOBITO." — This little flycatcher was found in low trees and among the thinner brush, always near the ground.

Six specimens, adults of both sexes, were taken at San Juan and Santa Fé, in April and May.

84. **Myiarchus sagræ** (Gundl.). "BOBITO." — Common in the pine woods, but not observed elsewhere in the island.

Seven specimens were taken at Santa Fé, Callebonita, and Jucaro, in April, May, and June.

85. **Tyrannus dominicensis dominicensis** (Gmel.). "PITIRRE." — The Gray Kingbird is abundant in the pine woods and scattered palmettos, but avoids the denser forest.

Seven specimens were taken at Santa Fé, Hospital, Callebonita, and Jucaro, in May.

86. **Tyrannus cubensis** Richmond. "PITIRRE DE AGUA." —The huge Cuban Kingbird is rare in the Isle of Pines. Only six were seen, of which five were shot. They were always near water. The natives say that this tyrant-bird catches small fish in the streams after the manner of a kingfisher; the stomachs of those taken, however, contained only remains of insects and a few berries.

Five specimens were taken at Santa Fé, La Vega, Almacigos, and Mal Pais, in May.

None of the Isle of Pines tyrant-birds differ in any way from those of Cuba.

87. **Galeoscoptes carolinensis** (Linn.). "ZORZAL GATO." — A regular migrant or winter resident, often seen during March, 1902, and once observed in April, 1904. Recorded from the island by Poey, Cory, and Gundlach.

88. **Mimus orpheus** (Linn.). — Given as occurring in the Isle of Pines by Cory, the mockingbird is said by the natives to inhabit the south coast in small numbers. None were seen on either trip.

89. **Myadestes elizabeth retrusus** subsp. nov.

"REISENOR."

Type and only specimen from Pasadita, Isle of Pines, adult male, no. 13,435, Coll. of E. A. and O. Bangs. Collected May 25, 1904, by W. R. Zappey.

Characters.—Similar to true *M. elizabeth* (Lembeye) of Cuba in size and proportions, but much paler in color; general color above hair-brown (olive brown in true *M. elizabeth*); ear coverts much paler, wholly lacking the tawny tinge of these parts in true *M. elizabeth*; the ochraceous line running from eye to frontal apex much paler and less conspicuous; eye-ring much paler.

Measurements.—Type, adult male: wing, 88.5; tail, 82; culmen, 12.

The Isle of Pines Solitaire is very rare and occurs in the densest forests only, where, on account of its retiring habits and dull coloration, it is very hard to shoot. Its loud, ringing song can be heard a great distance, and is almost startling in the still forests in which the bird lives. The stomach of the only specimen taken contained a few berries and the remains of insects.

The form can be told at a glance from Cuban specimens on account of its very much paler coloration, and is a strongly marked subspecies.

90. **Mimocichla rubripes rubripes** (Temm.). "ZORZAL." —A common species, found throughout the island. It keeps rather more to the brush and the woods than does *Merula migratoria*, which it otherwise much resembles in habits. It is a very conspicuous bird as it runs along the ground or hops about in the brush, with wings lowered and tail thrown upward.

Seven specimens, adults of both sexes, were taken at Santa Fé, San Juan, Hospital, and Callebonita in April and May. These seem wholly referable to true *M. rubripes*, differing only in that the rufous tinge of the belly is slightly paler and less extensive.

91. **Polioptila cærulea** (Linn.).—The Blue-gray Gnatcatcher was found in the island in March, 1902, though none were seen

on the last trip. It is also recorded from the Isle of Pines by Poey.

92. **Vireosylva calidris barbatula** (Cab.). "PREDICADOR." — A rather common bird in the Isle of Pines, frequenting trees of medium height. The iris is red-brown.

Ten specimens, adults of both sexes, were taken at Jucaro, Callebonita, and Santa Fé, in April and May.

93. **Vireo gundlachi** Lembeye. "JUAN CHIVI."— Gundlach's Vireo is very rare in the Isle of Pines. One pair was found in some brush and small trees at Callebonita, and secured May 3. These were all that were seen. The natives knew the bird, but said it was an uncommon species.

The two specimens secured differ somewhat from Cuban skins and more material might or might not bear out these differences. If it did, the form from the Isle of Pines would be worth recognizing as a subspecies. The male differs from Cuban males in being paler on the cheeks with much more of a buffy tinge there ; the female is paler throughout than in Cuban examples, and considerably lighter in color below. The iris in this form is light brown.

94. **Corvus nasicus** Temm. "CAO."— The Crow was found sparingly, usually in pairs, near the Cienaga. It is a restless bird and has a habit, when one comes within sight, of hovering over one's head high in air screeching and scolding continuously. The natives sometimes tame the Crow and teach it to say a few words. The iris is dark red.

Five specimens, adults of both sexes, were taken at La Vega and Pasadita in April and May.

95. **Progne cryptoleuca** Baird. "GOLONDRINA."— Not common in the Isle of Pines. It was seen several times, but no nesting place was found. Palmer and Riley found small colonies in the pines at Managua.

96. **Petrochelidon fulva fulva** (Vieill.). "GOLONDRINA."— Like the Martin, the Cliff Swallow was not found nesting in any region visited by Zappey. It was seen flying several times. Palmer and Riley found it abundant in the lowlands near Nueva Gerona.

97. **Mniotilta varia** (Linn.).— Recorded from the island by Poey, and seen on the March, 1902, trip.

98. **Compsothlypis americana** (Linn.).— Recorded from the island by Poey, and also seen in March, 1902. Without specimens it is of course impossible to tell to which subspecies, as now recognized, this record applies.

99. **Chrysocantor petechia gundlachi** (Baird).— The Mangrove Warbler was not observed in the Isle of Pines on either trip, though it was common at the opposite coast of Cuba at Batabano where a series of specimens was taken while waiting for a vessel to sail for the island.

It is recorded from the island by Poey and by Cory.

100. **Dendroica cærulescens** (Gmel.).— Recorded from Isle of Pines by Poey and by Cory and not uncommon in March, 1902. None were seen in 1904.

101. **Dendroica virens** (Gmel.).— First recorded from the island by Poey, and later Gundlach says that he took his first specimen of this species in the Isle of Pines in January, 1855.

102. **Dendroica dominica dominica** (Linn.).— This is another species recorded by Poey and found in March, 1902, but not seen in 1904.

103. **Dendroica discolor** (Vieill.).— Given by Poey from Isle of Pines, but not observed on either of the trips made to the island by Zappey.

104. **Dendroica palmarum palmarum** (Gmel.).— Recorded from Isle of Pines by Cory and found there in March, 1902, but not on the second trip.

105. **Seiurus noveboracensis** (Gmel.).— Recorded by Poey and seen in March, 1902.

106. **Teretistris fernandinæ** (Lembeye). "CHINCHILETA." — This beautiful little ground warbler inhahits the thick, dense woods and is probably commoner than it appears to be. It was not often seen, however.

Three specimens, two males and a female, were taken at Pasadita and Callebonita, in May and June. These are precisely like Cuban ones.

107. **Geothlypis trichas** (Linn.).— Recorded by Poey from Isle of Pines. The subspecies to which this record applies is of course somewhat uncertain. Ridgway identified a series of birds taken in western Cuba by Palmer and Riley as *ignota*, and all

birds from eastern Cuba as *brachidactyla*. Judging from this the form wintering in the Isle of Pines should be *ignota*.

108. **Setophaga ruticilla** (Linn.). — Recorded by Poey, and found quite commonly in March, 1902. None were observed in April, 1904.

109. **Holoquiscalus gundlachii** (Cassin). "CHICHINGUACO." — Common in more open country, pastures, and ploughed fields. When the natives are ploughing, the grackle, often in great numbers, follows the plough to pick up grubs and the like that are turned up. It also, like the Ani, alights on the backs of horses and cattle to pick off ticks. The male, owing to the vertically placed feathers in the tail, presents a curious appearance when on the wing.

Nine specimens, both sexes, were taken, all at Santa Fé in April and May.

These skins average a little smaller with smaller bills than Cuban ones, and are, perhaps, a trifle duller in coloration, but in all these points Cuban birds vary, and there does not appear to be any real character by which the Isle of Pines grackle can be distinguished.

The series measures as follows : —

No.	Sex.	Wing.	Tail.	Tarsus.	Exposed culmen.
13,274	♂ ad.	137	120	36	33
13,275	♂ ad.	139	122	37	33.5
13,276	♂ ad.	140	128	36	33.5
13,277	♂ young ad.	135	115	35.5	34
13,278	♂ young ad.	131	107	34.5	33
13,279	♂ young ad.	136	110	37	33
13,281	♀ ad.	135	107	35	31.5
13,282	♀ ad.	123	102	32	28

110. **Ptiloxena atroviolacea** (d'Orb.). "TOTI." — Probably a rare bird in the Isle of Pines as none were observed. The natives, however, know the "Toti" from the "Chichinguaco." It is recorded from the island by Poey and by Gundlach.

111. **Icterus hypomelas** (Bonap.). "SOLIBIA." — Common, especially among the pines. The oriole feeds a good deal among the flowers of various shrubs and trees, and its head is often daubed with juice and pollen from these.

Fourteen specimens, adults of both sexes and young including nestlings, were taken at Jucaro, Hospital, Callebonita, and Santa Fé in April, May and June. In birds from the Isle of Pines the yellow color of rump, thighs, and wing-coverts is a little paler than in Cuban examples, as is also the brownish yellow of under tail-coverts and anal region, with less of this color and rather more black than in Cuban specimens; but these differences are not very tangible and the Isle of Pines bird is not different enough to be formally separated as a subspecies.

112. **Agelaius assimilis** Lembeye.[1] "Toti la Cienaga." — During the period spent near the Cienaga — April and May — all the birds of this species, that probably at some time of year scatter through the swamp to breed, were congregated in one flock that kept to some large trees at the edge of the Cienaga. The breeding season was not near at hand as the testes of the males were not enlarged, neither had it just passed as no very young birds were seen.

The notes of this species resemble those of the common Redwing (*Agelaius phœniceus*) but are lower and more wheezy, sounding, when a number are calling together, much like the chirping of insects.

In the adult male the wing is colored like that of *A. phœniceus floridanus*, but younger males have the shoulder black, as in the adult female, except that some of the feathers are irregularly tipped and spotted with red and tawny, the amount of these colors varying much, from individuals with scarcely any to those that begin to show the characteristic markings of the adult.

Of all the Icteridæ this is probably one of the rarest and most local species, being known only from the Zapata Swamp in Cuba and the Cienaga in the Isle of Pines.

Seven specimens, both sexes, were taken, all at the edge of the Cienaga in April.

113. **Sturnella hippocrepis** (Wagler). "Sabanero." — The Meadowlark is common in pastures and fields and in the edge of the pine woods, and is very tame and unsuspicious.

Six specimens, adults of both sexes, were taken at Santa Fé,

[1] *Ex* Gundlach, MSS.

Jucaro, and Callebonita in April and May. These are similar to Cuban specimens, although they average more yellow on the thighs. Some Cuban skins, however, have the thighs nearly as yellow as Isle of Pines birds.

114. **Dolichonyx oryzivorus** (Linn.). — A casual migrant to the Isle of Pines, recorded by Cory and by Gundlach, but not observed on either trip.

115. **Spindalis pretrei pinus** subsp. nov.

"CABRERO."

Type from Santa Fé, Isle of Pines, adult male, no. 13,317, Coll. of E. A. and O. Bangs. Collected April 18, 1904, by W. R. Zappey.

Characters. — Similar to true *Spindalis pretrei* (Lesson) of Cuba, but considerably larger with a larger bill. There is also a slight average difference in color, the male of the new species being rather paler and more purely yellow, less rufous-orange and tawny-orange, on nuchal collar, lower rump, and chest, than in Cuban examples; and the black cap extends rather farther backward, encroaching more upon the yellow of the nape band. The female appears not to differ in color, though our specimens are slightly paler and grayer than Cuban ones, but they were all taken in spring and early summer, whereas the Cuban examples we have compared them with were shot in December. The difference therefore is probably seasonal.

Measurements: —

No.	Sex.	Wing.	Tail.	Tarsus.	Exposed culmen.
13,311	♂ ad.	75	57.5	18.5	12.5
13,312	♂ ad.	74.5	57	18	12.5
13,323	♂ ad.	76.5	59	18.5	13
13,314	♂ ad.	77	57.5	18	12
13,315	♂ ad.	71	54	19	12
13,316	♂ ad.	73.5	56.5	19	12
13,317	♂ ad.	75	59	19.5	12
13,318	♂ ad.	75.5	60	18.5	12.5
13,319	♂ ad.	72.5	55	18	12
13,320	♂ ad.	73	57	19	11.5
13,321	♂ ad.	72.5	57	18	12

No.	Sex.	Wing.	Tail.	Tarsus.	Exposed culmen.
13,322	♂ ad.	75	57.5	18	12
13,310	♀ ad.	69	54	17.5	12
13,313	♀ ad.	68	52	17	12
13,324	♀ ad.	69	50	17.5	12
13,325	♀ ad.	71	55.5	18	12
13,326	♀ ad.	68	53	17.5	12
13,327	♀ ad.	67	53.5	18	11
13,328	♀ ad.	69	52	18	12.5
13,329	♀ ad.	67	50	17	12
13,330	♀ ad.	72	52	18.5	11.5

The Spindalis is a conspicuous and rather common bird in the Isle of Pines, frequenting the pines and a tree (name not known) that bears a pink blossom. Both the males and females sing, the song being a low, weak warble.

Twenty-one specimens, adults of both sexes, were taken at Santa Fé, Jucaro, Callebonita, Pasadita, and San Juan, in April, May, and June. These differ from Cuban examples, as has been pointed out by Ridgway in *Birds of North and Middle America*, in larger size and bigger bills, and in addition show a slight average difference in color.

116. **Tiaris olivacea olivacea** (Linn.). "Tomequin de la Tierra." — A rather common bird in the Isle of Pines, in the brushy country, and particularly fond of thorn bushes, and one species of palm upon the berries of which it feeds.

Nine specimens, adults of both sexes, were taken at Santa Fé and Callebonita in April, May, and June.

Ridgway in *Birds of North and Middle America* (Part I, p. 531, footnote) speaks of the slightly larger size and duller colors of the male Grassquits from Cuba, Grand Cayman, and Little Cayman as compared with those from Haiti and Jamaica. The series from the Isle of Pines bears out both peculiarities — larger size of the males and duller colors — but the differences are very slight and hardly sufficient to base a new form upon. The specimens measure as follows : —

No.	Sex.	Wing.	Tail.	Tarsus.	Exposed culmen.
13,301	♂ ad.	49	37.5	15.5	9
13,303	♂ ad.	47.5	37.5	16	9
13,304	♂ ad.	49.5	38	15.5	9.5

No.	Sex.	Wing.	Tail.	Tarsus.	Exposed culmen.
13,306	♂ ad.	51.5	40	16	9
13,307	♂ ad.	50.5	39	15.5	9
13,308	♂ ad.	50.5	38.5	15.5	9
13,309	♂ ad.	52	41	15.5	9.5
13,302	♀ ad.	47	37.5	15	9
13,305	♀ ad.	47	36	15.5	8.5

117. ? **Tiaris canora** (Gmel.). "Tomequin del Pinar."— Under the name *Passerina collaris* Vig., a synonym of the Melodious Grassquit, Poey recorded this bird from the Isle of Pines. Cory also gives the species from the island, but may have taken it directly from Poey. Poey does not include the common Yellow-faced Grassquit in his list, and we consider this a very doubtful record probably due to confusion of names.

At all events, it must be very rare, as nothing was seen or heard of it in the Isle of Pines by Palmer and Riley or by Zappey.

118. **Melopyrrha nigra** (Linn.). "Negrito."—The Cuban Bullfinch appears to be restricted in the Isle of Pines to the dry, brushy country south of the Cienaga and even there is not at all common.

One male was taken at Puenta del Este, on April 29.

119. **Passerculus sandwichensis savanna** (Wilson).— The Savanna Sparrow was taken in March, 1902, but on the second trip to the island, beginning in April, none were seen.

120. **Coturniculus savannarum passerinus** (Wilson). — The Yellow-winged Sparrow was also found in March, 1902, and was not observed during the 1904 trip. None appear, therefore, to breed in the Isle of Pines, and those seen in March, 1902, undoubtedly were northern birds. There is, however, a resident breeding race in Cuba, as well as northern birds that pass the winter there.

STUDIES ON THE PLANT CELL.—V.

BRADLEY MOORE DAVIS.

SECTION IV. CELL UNIONS AND NUCLEAR FUSIONS IN PLANTS.

THE forms of cell unions and nuclear fusions in plants fall into two groups: (1) those which obviously have no sexual significance attached to them, and (2) those which are evidently sexual acts. But apart from these simple divisions there are some very interesting conditions in which it is far from easy to determine whether certain events have a sexual significance either physiologically or phylogenetically. The real test of such problems should lie in the evolutionary history of the processes involved, for every sexual condition in plants has probably developed in obedience to the same physiological demands and in an essentially similar manner. However, we cannot apply the evolutionary test in many cases where we have little evidence of the developmental history of the group and such forms must rest for the present as unsolved problems. We shall treat them in special connections later in the paper.

The material of this section will be presented under the following heads:—

1. Protoplasmic connections between cells (plasmodesmen).
2. Sexual cell unions and nuclear fusions.
3. Asexual cell unions and nuclear fusions.

1. Protoplasmic Connections between Cells (Plasmodesmen).

It has been known for a great many years that the walls between the cells in some plant tissues and more especially between the cells of filaments in certain thallophytes were crossed by delicate strands of protoplasm so that contiguous protoplasts were not entirely separated from one another. This fact

offers at once many interesting possibilities of explaining the close association of many cells and tissues, not alone in delicate dynamic interrelations but even in the exchange and distribution of food material and other products of metabolism. It makes possible the conception of the plant body as a finely adjusted community of protoplasts intimately and sensitively related to a great degree in all parts, a view very different from the old idea of a cell republic. As might be expected, these speculative possibilities were conceived and expressed by such leaders as Hofmeister, Nägeli, Sachs, and Strasburger long before the detailed study of protoplasmic connections gave the mass of evidence upon which have been based the more elaborate conceptions of recent years.

The most obvious protoplasmic connections between cells may be found in the thallophytes where as in the Rhodophyceæ, Volvox, and in certain fungi, the cells in younger structures may be observed under comparatively low magnification to be united by strands of protoplasm so broad as to quite exclude them from the category of fibrillæ. Some of these structures are so conspicuous that it is surprising that more was not made of them by early writers and that they have not been more extensively investigated recently. The greater part of the papers have been on the very difficult phase of the subject, the structure of pores and pits in the tissues of higher plants. The literature treating of protoplasmic connections is too extensive to be given detailed treatment in the compass of this paper. The best review of the subject is that of Strasburger (:01), supplemented by the more recent paper of Kienitz-Gerloff (:02).

The earlier papers on the protoplasmic connections in higher plants, following the establishment of perforations of sieve-plates by Sachs and Hanstein, appeared during the years just preceding and following 1880. Thus Tangl ('79–'81) described very clearly the communications between the endosperm cells of *Strychnos nux vomica* and Phœnix (see Fig. 16, a). Tangl noted the resemblance of the complex of connecting threads to the arrangement of spindle fibers associated with the simultaneous division of the protoplasm in the endosperm but was cautious in assuming a relationship, suggesting that the resemblance might be superficial.

Strasburger ('82, p. 246) discussed the permeability of cell walls and Gardiner ('88) gave a general treatment of the subject without, however, any figures to illustrate his conclusions. Gardiner discovered for a large number of forms in a wide variety of families that the pit membranes were frequently pierced by protoplasmic fibrils and that in some cases the fibrils traversed the entire thickness of the cell wall. A more detailed study with better methods, supplementing his former work and accompanied by figures, was published by Gardiner, in 1898, this paper forming an important contribution to the subject. Gardiner (:00) announced himself strongly in favor of the view that the protoplasmic connections between cells were derived from spindle fibers of nuclear figures concerned with each cell division, a possibility which had been suggested by previous writers (Tangl, '79–'81; Russow, '83).

Kienitz-Gerloff ('91) gave an excellent account of the protoplasmic connections in a number of forms, some of them pteridophytes, but especially for *Viscum album*, and followed the history of the wall formation, showing that the spindle fibers disappeared completely before the development of the connecting strands of protoplasm. Kuhla (:00) followed Kienitz-Gerloff with more extended studies on the same form, *Viscum album*, tracing the protoplasmic fibrils between the cells in all the chief tissues and establishing the protoplasmic connections throughout the individual to an extent that was not known before. Hill (:01) described the structure of the sieve-tubes of Pinus, dealing especially with the formation of callus and the conversion of the connecting threads of protoplasm into strings of slime. An excellent review is also given of the work of Russow and others, particularly upon sieve-tubes. Kohl ('97) describes clearly protoplasmic connections between the cells of moss leaves.

A classification of protoplasmic connections was suggested by Kohl (:00) who distinguished between the solitary state when each fibril pierces the cell wall independently of its neighbors (Fig. 16, a and b) and a grouped condition when a number of fibers arise close together at the bottom of a pit and pierce the pit-membrane or middle lamella in a spindle-shaped arrangement,

reminding one of the central spindle of a mitotic figure (Fig. 16, c). In general the two types of protoplasmic connections are not found together in the same cell or tissue.

A new point of view was introduced into the discussion by the very important paper of Strasburger, in 1901. He considered the protoplasmic connections as sufficiently clearly differentiated structures to rank as organs of the cell and proposed for them the name plasmodesmen. Strasburger in agreement

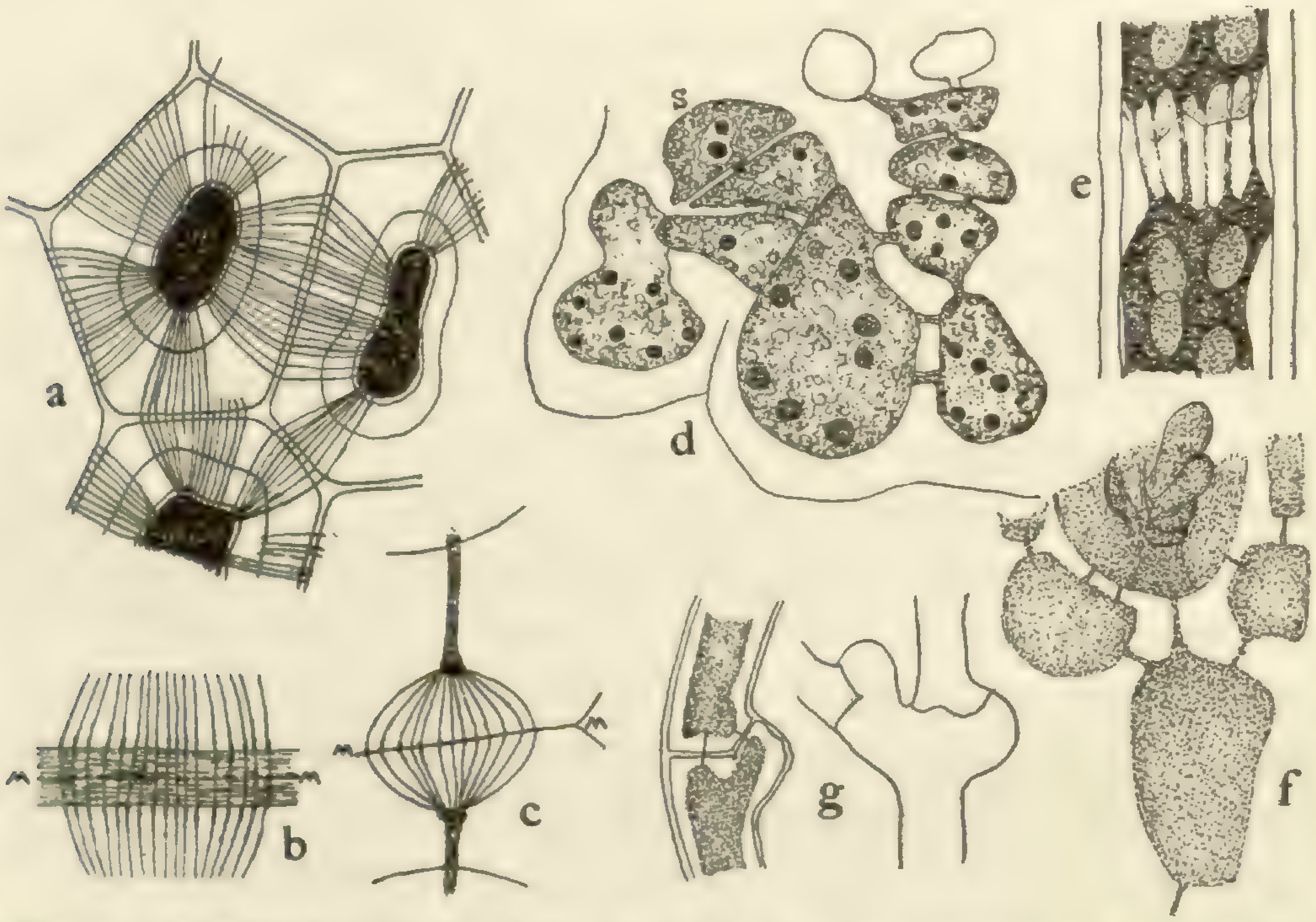

FIG. 16. — Protoplasmic connections between cells of plants. *a*, endosperm cells of *Strychnos nux vomica*; *b*, details of the solitary fibers in the same form, (*m*) middle lamella; *c*, grouped fibers at bottom of pit in endosperm of Phytelephas and crossing the pit membrane in a spindle-shaped figure: *d*, cell connections around the sporophytic portion of a developing cystocarp of Champia, (*s*) sporophytic elements; *e*, fibers between cells of Cladophora; *f*, cell connections around the ascogenous elements in Laboulbenia; *g*, clamp connections in Pleurotus (*a*, after Tangl, '79-'81; *b* and *c*, Kohl, :00; *d*, Davis, '96 b; *e*, Kohl, :02; *f*, Thaxter, '96; *g*, Meyer, :02).

with Kienitz-Gerloff opposed the view that the plasmodesmen were in any way derived from or related to the spindle fibers associated with the formation of cell plates. He believed them to be developments of the outer plasma membrane as he likewise considers the cilia in certain zoöspores (see account of zoöspore and sperm in Section III, *Amer. Nat.* vol. 38, pp. 571, 576, 1904). Strasburger also holds that pores are formed in the cell walls by the fermative activities around plasmodesmen. A

recent short paper by Michniewicz (:04) describes clearly the plasmodesmen in Lupinus, especially in their relation to masses of intercellular protoplasm which are discussed at the end of this portion of the section.

It is not clear whether all protoplasmic connections may be considered in the same class, as Strasburger would have us believe, or whether there may not be some confusion between the broader cell connections which are especially conspicuous in the thallophytes and certain tissues (sieve-tubes, laticiferous vessels), and the delicate protoplasmic fibrils (plasmodesmen) so general throughout all tissues of higher plants. As is well known, the cells in actively growing regions of the red algæ are connected by broad strands of protoplasm that are obviously left by the cleavage furrow which constricts the protoplasm of daughter cells but does not entirely separate them. These openings may become partially blocked in older portions of the plant by the deposition of material so that the connections are finally fibrillar but they frequently remain open for long periods, particularly in regions where the nutritive processes are active as during the development of cystocarps. At this time new fusions may be developed between neighboring cells (auxiliary cells) so that they become connected in an elaborate network around the cells or filaments (sporophytic) that develop the carpospores (Fig. 16, d). The Phæophyceæ also furnish frequent illustrations of connecting fibrils especially in the Fucales and Laminariales where the cells of internal filaments are sometimes connected by conspicuous strands. Certain elongated filaments which traverse the central region of the larger brown algæ show a complicated group of fibrils that strikingly resembles the protoplasmic connections piercing the sieve-plates of higher plants. Broad protoplasmic connections are conspicuous between the cells of some of the filamentous Cyanophyceæ (Stigonema, Tolypothrix) and in the Chlorophyceæ have been reported for some species of Cladophora (Kohl, :02; Fig. 16, e) and for Chætopeltis, one of the Mycoideæ. They do not seem to be present in the Conjugales as was at first reported by Kohl ('91) whose cells show a great degree of physiological independence. In Volvox, studied by Meyer ('96), each cell of the

sphere is connected with its neighbors generally by six strands of protoplasm, only a few of which could possibly be left by the successive cell divisions. The majority must have developed as outgrowths from the plasma membrane of the cell.

Numerous instances of cytoplasmic connections among the fungi have been reported by many authors. A general review of the subject is presented by Kienitz-Gerloff (:02) and in a lengthy paper of Meyer (:02). The protoplasmic connections fall into two groups: (1) those that remain in the center of the wall after a cell division, and (2) the lateral unions and clamp connections which are developed entirely independently of cell division. Connections of the first type, *i. e.*, those between daughter cells, appear to be very general in the Ascomycetes and Basidiomycetes and are essentially similar to the strands between cells of the Rhodophyceæ. They are especially well illustrated in members of the Laboulbeniaceæ (Thaxter, '96; see Fig. 16, f). In the second group are the clamp connections (Fig. 16, g), characteristic structures of the tissues of fleshy forms of the Basidiomycetes, and the lateral unions between cells of closely entangled hyphæ which are well known in a number of forms and have been followed in cultures from germinating spores. It is probable that the fusions between sporidia in the smuts are also of this class, although De Bary and others have attached sexual significance to the phenomenon (especially as illustrated by Tilletia). Harper ('99a) has studied the fusions of the conidia of Ustilago and finds that they concern the cytoplasm alone. However, Federley (:03–:04) has reported a nuclear fusion in one species (*Ustilago tragopogonis pratensis* Pers.) but states that others agree with Harper's account. Extensive experiments of Brefeld have shown that the fusions of sporidia depend largely upon the character of the nutrient media and are less likely to occur when the conditions are favorable. He considers the fusions as purely vegetative processes comparable to the unions of germ tubes of spores (*e. g.*, Nectria, Sclerotinia, Rhyparomyces, etc.) into a common mycelium and to the connections between hyphæ of Basidiomycetes. Recent studies of Blackman (:04 a) indicate also that sexual processes should not be expected at this period in the life his-

tory of smut or rust. One of the best discussions of cell fusions in the fungi is that in Harper's paper ('99 a), noted above.

Although most of the protoplasmic connections in higher plants are of the fibrillar character there are some notable illustrations of broad openings between cells, even more conspicuous than those in the red algæ. Such may be found in the pores of sieve-plates traversed in their early stages by strands of protoplasm that later disappear, and even better illustrations are the unions between cells composing laticiferous vessels. But the most interesting conditions are those associated with the nutrition of the eggs of certain cycads. Goroschankin ('83) first noted for the cycads pores or canals in the egg-wall of Ceratozamia and described communications between the protoplasm of the enveloping cells of the jacket and the egg. The subject is closely associated with the explanation of the proteid vacuoles in the eggs of gymnosperms which Arnoldi believed to be nuclei that had migrated from the surrounding cells. The conclusions of Arnoldi have not been sustained (see Sec. III, *Amer. Nat.*, vol. 38, pp. 591, 592, 1904) but the presence of pores in the egg-wall of gymnosperms is likely to prove very general with further investigation. A recent paper by Miss Isabel Smith (:04) gives an account of haustoria-like processes from the egg of Zamia which pass through the pores of the egg-wall into the cells of the jacket, where they are in direct contact with its protoplasm. These pseudopodia-like processes of the egg apparently absorb material from the cells of the jacket as is indicated by the character of their staining and the streaming movement towards them of the protoplasm in the jacket cells. The relation of the plasma membrane of the processes from the egg to that of the jacket cells is not clear but probably they are merely in contact and not in open communication. The ovules of cycads seem to offer an especially favorable subject for the study of pore formation and the intimacy of protoplasmic connections between cells.

It seems very clear that the cytoplasmic connections in the Rhodophyceæ, Volvox, fungi, and between the egg and jacket cells of cycads involve very much more substance than is generally present in the delicate fibrillæ of higher plants. Meyer

(:02, pp. 167, 168) seems justified in emphasizing their resemblance to pseudopodia rather than to any other structure of the cell. If they should finally be connected by intergradations with the exceedingly fine plasmodesmen of Strasburger, there would stand at one end of the series structures so thick as to be composed of a plasma membrane containing much cytoplasm in the interior and behaving like haustoria or pseudopodia and at the other end delicate fibrillæ. Viewing the problem of their relationships from the lower plants upwards, it is very difficult, if not impossible to follow Strasburger's theory that all cytoplasmic connections (plasmodesmen) are related to developments from the plasma membrane similar to cilia. They seem to be more of the nature of processes put out from the cytoplasm and when necessary penetrating cellulose walls probably in response to chemotactic stimuli since they are most conspicuous when metabolic activities are obviously important (*e. g.*, nourishment of the egg in gymnosperms and sporophytic generation of the red algæ).

In method of development we have seen that protoplasmic connections fall into two classes: (1) those that represent the incomplete separation of daughter cells, and (2) those that result from the coming together or fusion of protoplasmic outgrowths. The types of the first group are always in the beginning open communications which later may become largely or wholly closed; types of the second group may result in broad cytoplasmic fusions (*e. g.*, many fungi) but there is evidence that in many cases, especially among the higher plants, the two processes only come in contact so that the plasma membranes are applied to one another but do not actually unite. It does not seem probable that the two methods of development or the presence or absence of intimate protoplasmic union indicate a different kind of structure. They are more likely to be only varied responses to the demands for a more or less close association of neighboring cells. Broad communications are especially characteristic of regions where there is evidently an extensive demand for the nourishment of a cell or tissue, as in the eggs of the cycads or the cystocarp of the red algæ.

The functions of protoplasmic connections are probably vari-

ous. It is evident that they bind the whole plant body into a cell complex capable of very delicate interrelations. It is natural that physiologists, Pfeffer and others, should associate the structures with the phenomena of irritability as the paths over which stimuli may be transmitted from cell to cell and tissue to tissue. Several writers have reported their presence in unusual numbers in irritable structures of plants. The subject is discussed in great detail by Strasburger (:01, p. 533).

Besides conducting stimuli, there is much evidence that material may be transferred in solid or semifluid form by the protoplasmic connections from cell to cell and that in some instances there is actually a movement or flow of protoplasm. It is even known that nuclei may pass from cell to cell through pores in the wall, especially after some shock, as in the neighborhood of wounds (Miehe, :01), or when temperature is suddenly raised (Schrammen, :02). This literature and other references are discussed by Koenicke (:01; :04). A flow of protoplasm between neighboring cells of hyphæ has been reported by Reinhardt ('92) and Charlotte Ternetz (:00). That nuclei may pass through very small space is shown in the development of spores in the Basidiomycetes and in the growth of haustoria from the cells of hyphæ (Smith, :00). There are many forms known, especially among the thallophytes, where the communications between cells are so broad as to admit of a very free circulation of their contents. Such conditions are especially well illustrated in tissues around the developing cystocarps of the Rhodophyceæ and the ascocarp of the Ascomycetes, both structures apparently sporophytic in charater and dependent to a great degree upon the gametophyte as a host. It is believed that the vitality of protoplasm in sieve tubes, whose nuclei have degenerated and disappeared, is maintained through protoplasmic connections with neighboring cells and especially the companion cells, when present. Of course where an actual circulation of protoplasm is established between cells or tissues there is made possible a distribution of the products of metabolism in solid form that is very different from the usual diffusion in tissues through cell walls and plasma membranes.

It seems probable that there are really two forms of protoplasmic connections between cells in plants: first, those so intimate that the plasma membranes are pierced and become continuous openings inclosing a strand of granular cytoplasm within; and second, those in which the plasma membranes are merely applied to one another without open communication. The second form comprises the most delicate connecting fibrillæ, structures so fine that their minute structure is not understood and we do not know how intimate may be the application of the fibrillæ to one another or to the surface of the cells. These are the typical plasmodesmen of Strasburger which he considers as organs of the plasma membrane, kinoplasmic in character, and compares to cilia. The broad connections of the first group have exactly the structure that would be expected of fused pseudopodia, as Meyer pointed out. Whether the two types insensibly grade into one another or whether each is a development by itself is a problem of considerable interest, for if the former possibility prove true, Strasburger's conception and classification of plasmodesmen as organs of the cell will hardly seem justified.

When protoplasmic connections become so broad that cytoplasm flows or surges from one cell to another, an actual transfer of nuclei sometimes takes place. Such conditions may illustrate simply one extreme of the series of protoplasmic connections that we have just discussed, but many of them introduce some complexities, mainly through a certain resemblance to sexual processes, so that they should be treated apart from general protoplasmic connections. Some of them will be described later under the head of "Asexual Cell Unions and Nuclear Fusions."

Closely associated with protoplasmic connections is the interesting subject of intercellular protoplasm which is receiving some attention at present. The last papers are by Kny (:04) and Michniewicz (:04) who are studying conditions in the seed, especially of Lupinus. By various reactions and physiological studies, Kny has established an apparent identity of nature between an intercellular substance, sometimes with starch inclusions, and the cytoplasm of the neighboring cells. He considers this substance to be intercellular protoplasm, that is,

protoplasm outside of the cell walls, but connected with the cytoplasm within through fibrillæ. The intercellular protoplasm is thus conceived in organic connection with nucleated cells and from the studies of Townsend ('97) we know that non-nucleated protoplasm may live so long as it is united with nucleated, even though it be by very delicate fibrillæ. Michniewicz (:04) confirms Kny's conclusions for Lupinus and gives a very clear account of the fibrillæ which connect the masses of intercellular protoplasm with neighboring protoplasts. These studies make clearer a number of observations of several investigators (Sauvageau, Buscalioni, Schenk, Magnin, Strasburger, and others) who have noted similar conditions in the tissues of higher plants which are being investigated in detail by Kny. Some of the lower unicellular forms likewise exhibit an extracellular surrounding film or envelope, which may also be of a protoplasmic nature and consequently in the same position in relation to the protoplast as intercellular protoplasm. Thus it has been known for many years that the cells of the Peridinales, diatoms, and desmids possessed extracellular material, which some authors have considered in the nature of slimy excretions but others — Schutt ('99; :00a; :00b), Hauptfleisch ('88; '95), Müller ('98–'99) — have regarded as protoplasmic in character. Since the cell walls in these forms are known to possess pores, such extracellular substance must be in close association with the cytoplasm of the cell and it is not at all difficult to conceive of it as a part of the protoplasm. Some of the peculiar creeping movements of the diatoms and desmids are perhaps explicable upon these facts.

2. Sexual Cell Unions and Nuclear Fusions.

The test of a sexual act must lie with the history of the elements which fuse. If these are shown by their morphology and developmental history to be sexual cells or gametes then their fusion becomes a sexual process. There are cell and even nuclear fusions which have the physiological appearances of sexual acts but cannot be so considered because the elements concerned have plainly no relation to sexual cells, which are

developed at other periods of the life history, or to the primitive conditions always found with the origin of sex. These exceptional processes will be collected and described under the heading "Asexual Cell Unions and Nuclear Fusions," following this portion of the paper.

The union of gametes is generally termed fertilization. The evolution of the sexual process always tends towards a differentiation of the two sexual cells, one becoming more richly stored with food material and containing more protoplasm than the other. This latter gamete is always considered the female and is said to be fertilized when the male gamete, either as a motile sperm or reduced simply to a sperm nucleus generally with some accompanying protoplasm, fuses with it. The most evident morphological feature of fertilization is the close union of the gamete nuclei so that the chromosomes of both enter into the mitotic figure with which the new generation begins.

We shall not discuss the various forms of gametes nor their habits in different types of sexual reproduction. They have been described in two articles by the author on the origin and evolution of sex in plants (Davis, :01; :03). A detailed account of the sexual reproduction of well known types throughout the plant kingdom has been recently published by Mottier (:04b) under the title "Fecundation in Plants" a term which he prefers to fertilization. This paper gives in English the most extensive summary of our knowledge of the subject up to the date 1902 and will be read with especial interest as the most available expression in English of Strasburger's general views on the significance of the events connected with sexual reproduction.

A recent paper of Guérin (:04) is confined to an account of fertilization in the phanerogams which are treated in considerable detail. His discussion of double fertilization and parthenogenesis is of especial interest and will be taken up later.

Our purpose is to divest from the events of sexual cell unions and nuclear fusions all secondary and unessential processes and to outline, as are now understood, the fundamental phenomena. And to make the subject more plain we shall try to compare in their essentials the events of fertilization in plants with those

in animals. Probably the most important feature of fertilization is the close union of the gamete nuclei through which the chromosomes of both enter into the first mitotic figure of the new generation. It involves the organization of the first cleavage spindle, which inaugurates the new generation, and the history of the paternal and maternal chromosomes of the gametes at this time when the number becomes doubled.

Several zoölogical papers have developed in the past few years some very important conclusions concerning the individuality of the paternal and maternal chromosomes, as maintained during the fusion of the gamete nuclei and in the formation of the first cleavage spindle. It has been generally believed for some time — see general review in Wilson (: 00, p. 204) — that the fusion of gamete nuclei did not involve a coalescence of the chromosomes but that both paternal and maternal chromosomes maintained complete independence of one another and that all entered into the first cleavage spindle as structures quite as distinct as when formed during spermatogenesis and oögenesis. Häcker and Rückert have shown for Cyclops that the gamete nuclei divide side by side in the first mitosis following fertilization, and Häcker followed these double nuclei as far as the 16-celled stage when they were still distinct from one another. A few notable investigations of recent years have identified chromosomes accurately as maternal and paternal not only in the first cleavage spindle but through certain succeeding mitoses and finally at the period of gametogenesis when sperm and egg were again formed. The above principles have been established chiefly through a series of papers of Montgomery, the chief being a lengthy investigation of 1901, and contributions of Sutton (: 02 ; : 03) and Moenkhaus (: 04). They have given us clear evidence that the chromosomes not only maintain their complete individuality throughout successive generations but are distributed with gametogenesis and fertilization in various possible combinations that can be expressed by mathematical formulæ furnishing the basis for certain ratios that approximate the teachings of Mendel's law. We shall have occasion to refer to these in Section V when the subjects of gametogenesis, reduction of chromosomes, and hybridization will be discussed.

The same principles have been established in plants by recent investigations, some ot which deal with oögenesis and spermatogenesis and will be specially treated in the Section V while others treat of the behavior of the chromosomes when the gamete nuclei fuse and the sporophyte generation begins its development. The latter conditions concern the present discussion.

The history of the chromosomes in plants at the time when the gamete nuclei fuse (fertilization) is most accurately known for the pine. The last paper upon this type (Ferguson, :04) is very complete. Miss Ferguson gives a beautiful series of figures, some of which we have reproduced. The sperm nucleus comes in contact with the egg nucleus and sinks into the latter so that it lies in a depression, but as noted by Blackman ('98), it does not penetrate the membrane of the egg nucleus (Fig. 17, a). Both gamete nuclei thus lie side by side occupying approximately the same space formerly filled by the female. Each shortly gives evidence of preparation for the mitosis following fertilization (first cleavage spindle). The chromatin of the egg nucleus collects in a spirem, very close to the sperm, occupying a relatively small portion of this large female nucleus (Fig. 17, b). The chromatin of the sperm nucleus also takes position as a spirem on the side nearest its companion chromatin of the opposite sex. The remaining space of each nucleus is filled with a granular reticulum of a linin nature. At this time the amount of linin is extraordinarily large in proportion to the chromatin, suggesting that some of the latter substance has become changed to the former. Soon, delicate fibrillæ appear around the two spirems growing outward in various directions and finally crossing from one nucleus to the other. At the same time the two nuclear membranes become less distinct and shortly disappear. Thus the maternal and paternal spirems come to lie in a common area filled with delicate fibrillæ which run out to the granular cytoplasm that lay around the two gamete nuclei (Fig. 17, c). It should be especially noted that at no time in this history has there been a resting nucleus including both maternal and paternal chromosomes within a common nuclear membrane. The fusion of the gamete nuclei has only come with the actual formation of the first cleavage spindle.

The fibrillæ organize a multipolar spindle which is very variable in form, sometimes with broad poles of a multipolar diarch (Fig. 17, d) and at other times almost as pointed as in a typical bipolar spindle (Fig. 17, e). There are, of course, no centrosomes and the entire spindle in essentially of intranuclear origin. The history of its development recalls Miss Williams' account of the spindle in the pollen mother-cell of Passiflora (Sec. III, *Amer. Nat.*, vol. 38, p. 738, 1904). During spindle formation the spirems of the sperm and egg nuclei can be readily distinguished as was described by Blackman ('98) and Chamberlain

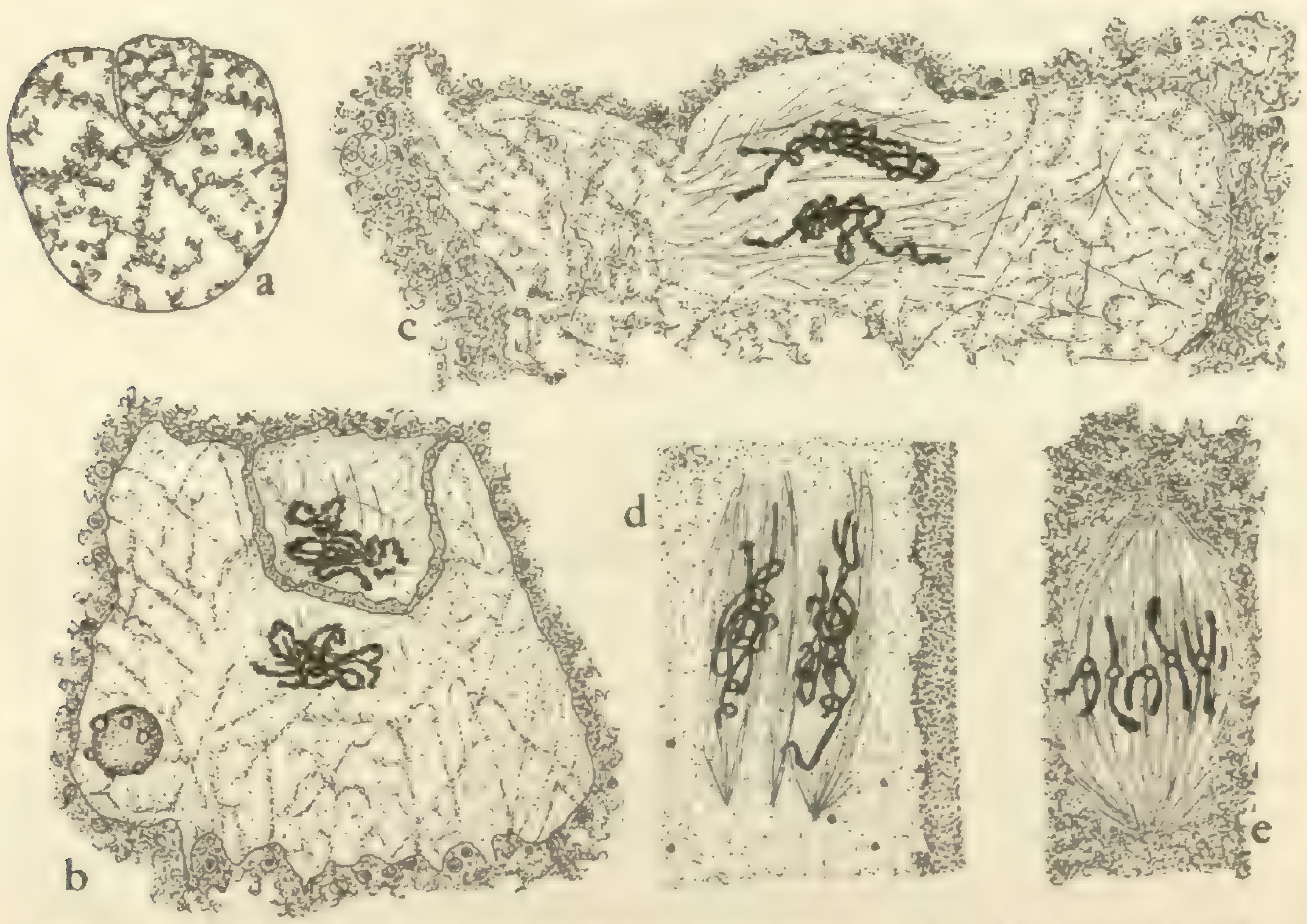

FIG. 17. — Fertilization in *Pinus strobus*. *a*, conjugating gamete nuclei; *b*, the gamete nuclei still separated, with nuclear membranes distinct, the maternal and paternal chromatin in two spirems; *c*, the nuclear membranes have disappeared and the two spirems lie close together surrounded by the fibrillæ which will organize the first segmentation spindle; *d*, prophase of the first segmentation spindle, of the multipolar diarch type, paternal and maternal spirems still distinct; *e*, metaphase of first segmentation mitosis, maternal and paternal chromosomes now indistinguishable, beginning to split in the middle region (after Ferguson, :04).

('99), but after the two sets of chromosomes are formed (twelve of each) the latter are brought so closely together at metaphase of mitosis that the paternal and maternal cannot be separated. All of the chromosomes are exactly alike and there is nothing in the form or size to distinguish one from another as certain

zoölogists have been able to do in some favorable animal types (Montgomery, Sutton, Moenkhaus). The chromosomes divide longitudinally in the usual way, the halves being drawn apart from the points of attachment of the spindle fibers (Fig. 17, e). It is clear that each daughter nucleus receives a full set of 24 daughter chromosomes, 12 of paternal and 12 of maternal origin, and that there is about an equal amount of chromatin from each sex.

It should be especially noted that in the process of fertilization in the pine there is at no time present what is generally called a fusion nucleus, *i. e.*, a single nucleus whose membrane incloses all the material of both male and female gamete nuclei. Such fusion nuclei, as we shall see, have been reported many times in other groups of plants than the gymnosperms where in many cases, however, detailed studies are very difficult and can scarcely be said to have even approached our knowledge of the pine.

Studies of other botanists indicate that the gymnosperms generally will show essentially the same conditions as in the pine. Thus Woycicki ('99) distinguished in Larix two groups of chromatin which he regarded as paternal and maternal. And Murrill (: 00) states for Tsuga that the chromatin of sperm and egg remain separate, forming two spirems, and only after their segmentation into chromosomes are the two sets of structures brought together in the first cleavage spindle. Land (: 02) figured the sperm nucleus of Thuja imbedded in a depression of the egg nucleus. Miyake (: 03a) noted that the sperm nucleus of Picea became more or less imbedded in the egg nucleus while the nuclear membrane remained intact, and the same author (Miyake, : 03b), reports similar conditions in Abies. Robertson (: 04) figures the sperm nucleus of Torreya lying within a depression in the female and with a large amount of granular cytoplasm (kinoplasm) at the side. Coker (: 03) states that the partition between the gamete nuclei of Taxodium "does not entirely disappear until immediately before the first division" although the two structures are closely united for some time previously while they pass to the bottom of the egg.

Lawson, studying Sequoia (: 04a) reports gamete nuclei of

about equal size whose chromatin contents unite in a fusion nucleus to form a common network in which male and female elements cannot be distinguished. A similar condition obtains in Cryptomeria, according to Lawson (:04b), where a fusion nucleus is described in which paternal and maternal chromatin are mingled together in a nucleus that passes through a short period of rest before the development of the first cleavage spindle. In view of the work on Pinus I think it may safely be questioned whether in Sequoia and Cryptomeria the maternal and paternal chromatin really does form a common network in the resting fusion nucleus. The subject is one very difficult of study and demands more stages than Lawson seems to have followed.

Fertilization in the cycads is not as completely known as for the conifers. Webber (:01) figures the sperm nucleus of Zamia imbedded in the egg nucleus but quite distinct from it as in the pine but the further history leading to the development of the first segmentation spindle was not followed. On the other hand Ikeno ('98b) described in Cycas the formation of a cup-like depression in the egg nucleus to receive the sperm nucleus which was said to enter and fuse completely with the female and the same author (Ikeno, :01) reports a complete fusion of the gamete nuclei in Ginkgo and did not distinguish the paternal and maternal chromosomes during the formation of the first segmentation spindle. However it is probable that more detailed studies among the cycads and in Ginkgo will show a behavior of the sperm nucleus together with the paternal and maternal chromatin essentially similar to that of the conifers. All investigations among the cycads and in Ginkgo agree that cytoplasmic structures of the sperm (blepharoplasts, cilia, etc.) are left behind in the cytoplasm of the egg before the gamete nuclei unite.

Our knowledge of the details of fertilization in the angiosperms is surprisingly meager. The only account of the chromatin is that of Mottier ('98 ; :04b, p. 176) for Lilium. He describes and figures the two gamete nuclei as uniting with their chromatin in the resting condition. The nuclear membranes disappear at the surface of contact and the two nuclei

fuse into one. The nucleoli unite and so thoroughly does the paternal and maternal chromatin seem to be mixed in the resting condition that the fertilized egg nucleus can scarcely be distinguished from the unfertilized. There would seem to be then a fusion nucleus in the lily with the chromatin in the resting condition. The figures and brief accounts of other botanists indicate that similar conditions may be expected in other angiosperms. But no one has followed the chromatin in the fusion nucleus through its later history, during the organization of the chromosomes preparatory to the first mitosis following fertilization. It would be very surprising if paternal and maternal chromatin did not remain entirely independent of each other as in the pine. The detailed study of fertilization in the angiosperms presents a very attractive subject for investigation.

Some very interesting conditions of fertilization have been

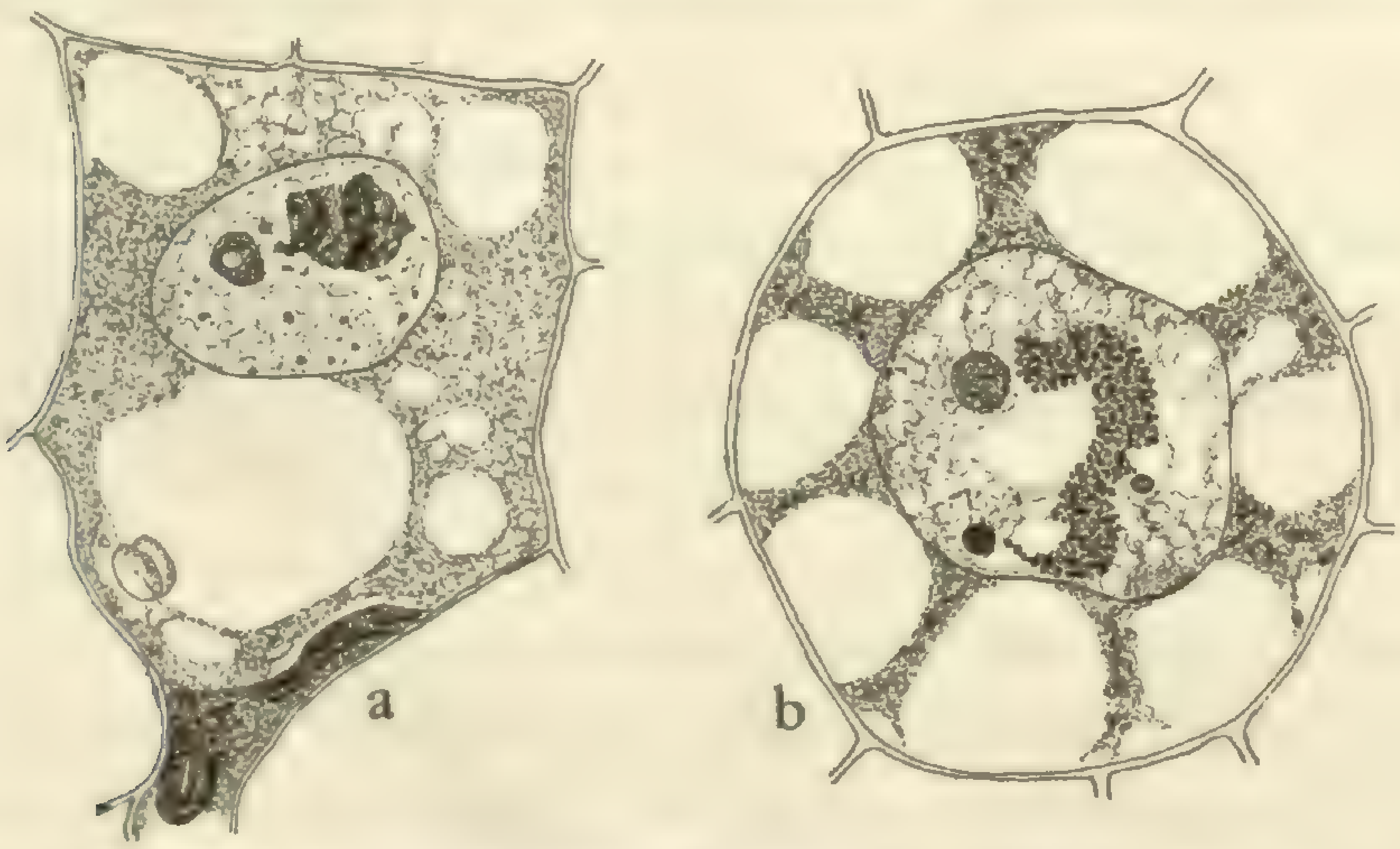

Fig. 18. — Fertilization in *Onoclea sensibilis*. *a*, sperm as a spiral band within the egg nucleus; *b*, later stage, the chromatin of the sperm much less condensed and more widely distributed in the egg nucleus (after Shaw, '98a).

described in the pteridophytes for Onoclea by Shaw ('98 a), confirmed by Mottier (:04 a; :04 b), and for Adiantum and Aspidium by Thom ('99). In these forms the male nucleus after leaving in the protoplasm of the egg all of the cytoplasmic structures of the sperm (blepharoplasts, cilia, etc.) enters the egg nucleus as a more or less spiral body which stains deeply and is evidently chiefly or wholly chromatic in composition (Fig. 18). Within the egg the dense structure of the sperm nucleus becomes looser by the separation of the chromatin granules (Fig.

18, b) but the form of the sperm can be recognized for a long time. The chromatin of the egg nucleus is in a resting condition at this period and the densely packed mass of paternal chromatin is very conspicuous in the loose, delicate network of the female chromatin. The mitosis following fertilization does not occur for several days so that it is not easily studied and the organization of the first cleavage spindle with the history of the maternal and paternal chromosomes has never been followed. But it is clear that we have in the pteridophytes a true fusion nucleus containing for several days both maternal and paternal chromatin within the same nuclear membrane.

There is only one paper that gives any details of fertilization in the bryophytes, a contribution of Kruch ('90) on the liverwort, Riella, which seems to have been generally overlooked in recent literature. After the sperm enters the egg, a male nucleus is organized which increases in size until it is about equal to the egg nucleus. The chromatin in both gamete nuclei is described and figured as forming 8 chromosomes which are organized before the fusion. The two gamete nuclei were observed, but not figured, in contact and it was not possible to distinguish in size the male from the female. This account is then very different from those of the pteridophytes since the sperm nucleus does not enter the egg nucleus but the two fuse side by side and with their chromosomes fully organized. There are, however, some points in Kruch's paper that require more extended investigation and confirmation in the light of modern research.

There is left only the group of the thallophytes where less is known about the detailed behavior of the chromatin during fertilization than in any region of the plant kingdom. The conjugation of the gamete nuclei has been observed in a number of thallophytes, representing all of the higher groups. All of the authors, with the exception of Chmielewski ('90 b) for Spirogyra, describe the product of conjugation as a fusion nucleus, *i. e.*, one in which the nuclear substance of both gametes is contained within a common nuclear membrane. The most detailed accounts of the fusion of gamete nuclei in the thallophytes are those for Fucus (Strasburger, '97 a; Farmer and Williams, '98).

The sperm of Fucus upon entering the egg loses its cytoplasm and passes rapidly to the egg nucleus as a deeply staining body resembling a plastid in form. This structure is the male nucleus whose chromatin is so densely crowded that it stains too deeply to show much structure. Arriving at the side of the female nucleus, about ten minutes after its entrance into the egg, the male nucleus flattens against the female and increases in size so that the chromatin appears less condensed. The male nucleus is then absorbed so that the paternal chromatin lies within a fusion nucleus but may be distinguished for some time as densely staining material at one side. A second nucleolus often appears in the fusion nucleus in the vicinity of the paternal chromatin and is probably associated with the entrance of the sperm nucleus, although it is not likely to have been brought in as an organized structure but developed later at the expense of material in the sperm nucleus. The fusion nucleus remains quiescent for from 20 to 24 hours during which time the paternal chromatin becomes so distributed that it can no longer be followed. Then two centrospheres with conspicuous radiations appear at opposite poles of the fusion nucleus and the first cleavage spindle is organized. There is no evidence that either of these centrospheres is brought into the egg by the sperm and both appear *de novo* and independently of one another.

The chief accounts of the fusion of gamete nuclei in thallophytes are as follows: Closterium and Cosmarium (Klebahn, '91); Rhopalodia (Klebahn, '96); Cocconeis (Karsten, :00); Sphæroplea (Klebahn, '99; Golenkin, '99); Œdogonium (Klebahn, '92); Coleochæta (Oltmanns, '98); Vaucheria (Oltmanns, '95; Davis, :04); Fucus (Strasburger, '97 a; Farmer and Williams, '98); Batrachospermum (Schmidle, '99; Osterhout, :00); Nemalion (Wolfe, :04); Basidiobolus (Fairchild, '97); Albugo (Wager, '96; Stevens, '99, :01 b; Davis, :00); Peronospora (Wager, :00); Pythium (Miyake, :01; Trow, :01); Achlya (Trow, :04); Araiospora (King, :03); Sphærotheca (Harper, '95); Pyronema (Harper, :00). Most of these papers with others on fertilization in the thallophytes are summarized by Mottier, (:04 b) in very convenient form for reference.

There is some confusion in the accounts of fertilization in

Spirogyra which should be thoroughly investigated. Chmielewski ('90 b) in a paper published in Russian and reviewed in the *Bot. Centralb.*, vol. 50, p. 264, 1892, described a fusion of the gamete nuclei in the zygospore and an immediate mitosis, without a period of rest, followed at once by a second division of the daughter nuclei. These mitoses give the zygospore four nuclei, two of which unite to form a final resting nucleus in the zygospore while the remaining two fragment and their products finally break down. This behavior offers an exception to all sexual processes so far known in the plant kingdom. There are some features which suggest a possible confusion with events as described in the zygospore of the desmid and the auxospores of certain diatoms.

The fusion nucleus in the zygospore of Closterium and Cosmarium (Klebahn, '91) divides into four at the time of germination and two of these break down while each of the others becomes the nucleus of the two new desmids that are formed. There is then in the desmids the division of the fusion nucleus into four but no secondary nuclear fusions as Chmielewski reports for Spirogyra. In certain diatoms, Rhopalodia (Klebahn, '96) and Cocconeis (Karsten, :00), there is a preliminary division of the nuclei in each of the two cells which form the auxospore. In Rhopalodia the mitoses are carried so far that four daughter nuclei are formed in each diatom and the protoplasm divides into two cells each of which fuses with a corresponding cell of the companion pair. In both types the superfluous nuclei break down so that the conjugating cells have each a single functional gamete nucleus. There are then complications in the Conjugales and the diatoms, which make nuclear studies of the sexual processes exceptionally difficult and we seem justified in reserving our judgment of the results of Chmielewski until confirmed. It seems possible that the mitoses following the germination of the zygospore in the Conjugales with the attendant nuclear degeneration are reducing divisions in a simple and primitive type of sporophyte generation but more detailed studies of nuclear behavior during the formation and germination of the zygospore will be necessary to settle the discussion.

We have now finished our account of nuclear fusions in the

sexual act (fertilization) but there remains for consideration the behavior of certain cytoplasmic elements introduced into the sexually formed cell, especially chromatophores and the blepharoplast. Since the blepharoplast bears a very close resemblance to the middle piece of the animal spermatozoon, which sometimes becomes a centrosome in the animal egg, a critical comparison of the behavior of these two structures during fertilization is full of interest.

Except for certain accounts of Spirogyra, to be described in the next paragraph, investigators agree that the chromatophores or plastids of gametes never fuse in the sexually formed spore. Plastids have not been found in the sperms of the gymnosperms, pteridophytes, nor bryophytes. The sperms of some algæ also appear quite colorless at maturity but careful examinations have shown in a number of forms a very small chromatophore in the early stages of development. Other less highly differentiated sperms are known to have chromatophores (*e. g.*, Sphæroplea, Cutleria, Volvox). Both gametes in the isogamous types of sexuality among the algæ always have chromatophores or plastids. These have been followed in detail through stages of fertilization in Ectocarpus by Berthold ('81) and Oltmanns ('99), and in Scytosiphon by Kuckuck ('98) where it is evident that they do not unite and there is no reason for believing that different conditions obtain among any of the lower forms such as Ulothrix, Cladophora, Hydrodictyon, etc., although detailed observations are greatly lacking on this point, chiefly because the conjugating cells are generally very small.

Early accounts of the formation of the zygospore of Spirogyra have reported some form of union of the chlorophyll bands of the two gametes. The last work upon the subject, Chmielewski ('90a), reviews the results of previous investigators and gives a detailed account of a species of Rynchonema (Spirogyra). Chmielewski claims that the chromatophore of the gamete (male) that passes over into the other cell (female) becomes disorganized as the zygospore develops. While the chlorophyll band of the female cell retains much of its color, that from the male becomes yellowish and breaks up into fragments which become scattered in the zygospore and finally break down. This inter-

esting account accompanied by clear figures gives an explanation far more in keeping with what we know and might expect of the behavior of chromatophores in resting spores. That the green chromatophore may temporarily become much modified in color and form is well known in some of the red and orange resting spores of the Volvocaceæ and the zygospores of the desmids. In some of these types the form and color of the chromatophores become quite lost for the time being so that studies on their behavior are very difficult. For these reasons it seems probable that the accounts of the fusion of the chromatophore in the zygospore of Spirogyra are incorrect. It is very interesting that the gametes of Spirogyra should be so sharply differentiated that the chromatophore of one should be reduced during conjugation in a manner that resembles very closely the behavior of the chromatophore in highly differentiated sperms.

There is no evidence that the pigment spots, so generally present in the motile gametes of lower forms, ever unite. They have been followed into the zygospore and after the germination of this cell and they remain entirely independent of one another as would be expected from their close relationships to chromatophores.

The fate of the blepharoplast will now be considered. This structure is especially interesting because of its close analogy to the locomotor apparatus of the animal spermatozoön, which is formed chiefly from one or more centrosomes generally with the coöperation of archoplasm (idiosome, Nebenkern). It is also claimed by a number of zoölogists that in some forms, at least, the centrosomes of the first cleavage spindle are derived from the spermatozoön.

All evidence indicates that the blepharoplast of the plant sperm is left behind in the cytoplasm of the egg when the male nucleus passes into the interior to unite with the female and that centrospheres when present, in the first cleavage spindle, are formed *de novo*. The fate of the blepharoplast is clearly known in Cycas (Ikeno, '98b), Zamia (Webber, :01) and Ginkgo (Ikeno, :01). Soon after the large top-shaped sperm of these forms enters the egg, the male nucleus slips out of the spiral blepharoplast, that partially invests it, and, leaving it with

other cytoplasm of the sperm at the end of the egg, passes quickly to the center to unite with the female nucleus. The blepharoplast remains near the periphery of the egg and may be recognized even after the gamete nuclei have united. It finally breaks down and its substance becomes lost in the cytoplasm of the egg. The most complete account of the history of the blepharoplast in the fertilized egg is that of Webber (: 01). We should naturally expect the first cleavage spindle in the cycads and Ginkgo to be developed as in the conifers. Ikeno (: 01) described clearly an intranuclear spindle in Ginkgo. In the conifers, as previously described, the first cleavage spindle is intranuclear and the fibers are developed freely from a mesh and form a broad poled spindle without centrospheres. So that not only does the blepharoplast break down at a distance from the egg nucleus but we have no reason to think that there is any place for a centrosome in the history of the first cleavage spindle in the gymnosperms.

We do not know clearly the fate of the blepharoplast in the egg of any pteridophyte or bryophyte, although Shaw's ('98a) studies on Onoclea indicate that it breaks down in the cytoplasm. Our knowledge of the thallophytes is equally incomplete as regards the history of the blepharoplast in the egg. But both Strasburger ('97a) and Farmer and Williams ('98) have agreed for Fucus that the two centrospheres at the poles of the first cleavage spindle develop *de novo* and independently of one another, and Williams (: 04b) holds the same view for the centrosphere which appears at the side of the fertilized egg of Dictyota. The sperms of the thallophytes are generally very small cells and it may prove a difficult matter to follow their blepharoplasts so that our opinions of events in these forms are likely to be largely inferential from our knowledge in higher groups.

We can safely say that there is no evidence that the blepharoplast ever enters into the first cleavage spindle which is certainly developed in the spermatophytes and probably in the pteridophytes without centrosomes or centrospheres. Where centrosomes or centrospheres are known for the first cleavage spindle in the thallophytes (Fucus and Dictyota), the observations indi-

cate that such structures have not come from the blepharoplast. Williams' (: 04b) recent work on Dictyota, while incomplete in the series of stages illustrating the fusion of gamete nuclei (fertilization), presents a very interesting comparison of the development of the first cleavage spindle in fertilized eggs with parthenogenetic eggs. In the fertilized egg there is regularly found a centrosphere which apparently divides into two that separate until they lie at opposite poles of the mature spindle. In the parthenogenetic egg, on the contrary, the spindle is multipolar and develops very irregularly from a kinoplasmic mesh which is intranuclear and there is no sign of centrospheres. Williams believes that fertilization enables the fusion nucleus to form *de novo* a centrosphere external to itself which is not possible for the nucleus of a parthenogenetic egg.

It should be noted that these conclusions are all against the view that the centrosome is a permanent organ of the cell and that the blepharoplast holds any direct relation to centrosomes when present in the first cleavage spindle and inferentially rather strengthens the doubt that the blepharoplast is derived from a centrosome, which point was discussed in our account of the sperm in Section III. However, Ikeno (: 04) in a paper which arrived too late to be treated in Section III, is very positive that blepharoplasts are centrosomes, presenting his evidence clearly, but his explanation of the conditions under which blepharoplasts are formed from the plasma membrane does not seem to me conclusive, especially in the light of Mottier's (: 04a) recent paper on Chara, which also could not be treated in Section III (see *Amer. Nat.*, vol. 38, p. 576, 1904).

3. Asexual Cell Unions and Nuclear Fusions.

As stated earlier in the paper, the test of a sexual act must lie with the history of the elements which unite, unless we choose to treat sexuality as a purely physiological process and disregard its relation to morphology in ontogeny and phylogeny. This relation is so precise, *i. e.*, sexuality is so firmly established as a fixed period in the life history of most organisms, that the biologist generally thinks of the sexual process as a part of the

life history, which must take place with as much regularity as the normal development of any organ. As a matter of fact, our knowledge of the structure of sexual elements and the events of sexual phenomena is almost wholly morphological and for the present at least it seems safer to treat and define sexuality from a morphological standpoint.

Under asexual cell unions and nuclear fusions we shall include a number of interesting phenomena which can be arranged in three groups: (1) cell fusions which have apparently no sexual relations; (2) cell fusions which are substitutes for a normal ancestral sexual process now suppressed; and (3) extraordinary modifications of what may have been originally sexual processes but which at present serve some peculiar and special function.

In the first group will be included the extensive union of swarm spores, or the amœboid elements derived from such, best illustrated in the development of plasmodia; also such cell fusions as are clearly for nutritive purposes, as is the union of the sporophytic portion of the cystocarp of the red algæ with auxiliary cells and probably also the fusion of sporidia in the smuts and the conjugation of yeast cells. The second group embraces the interesting fusions of the nuclei in teleutospores of the smuts and rusts and in the basidium with the previous history of the paired (conjugate) nuclei in the mycelium, perhaps also the nuclear fusions in the ascus, and such cell unions as have been reported preliminary to the apogamous development of the fern sporophyte. The third group includes the remarkable phenomenon in the embryo sac, the double fusions of the polar nuclei and the triple fusion of these with the second sperm nucleus, frequently called "double fertilization."

The well known union of the swarm spores of the Myxomycetes as amœboid cells (myxamœbæ) to form the plasmodium is one of the best illustrations of a fusion of protoplasm without sexual significance. In this general union of hundreds and perhaps thousands of small cells there are no nuclear fusions so far as is known, but simply the merging of the cytoplasm to form a large multinucleate unit. The whole phenomenon indicates a coöperative process which is probably economical of nutritive functions in the semiterrestrial conditions under which plas-

modia live. It is quite possible that the origin of sex may have been involved with some of the same principles as those which bring about the union of swarmers to form a plasmodium, but the added features of nuclear fusion together with the history of the sexually formed cells which become in higher groups the starting point of a sporophyte generation places the sexual act on a very much higher level of complexity.

There are some records of the union of several zoöspores or gametes to form a zygospore instead of the usual conjugation in pairs. The biciliate gametes of Acetabularia (De Bary and Strasburger, '77) sometimes conjugate in threes and large zygotes are figured with five pairs of cilia indicating that as many gametes entered into their formation. The gametes of Protosiphon, described by Rostafinski and Woronin ('77) as in the life cycle of Botrydium, are reported by them to unite at times several together and four are so figured. Klebs ('96, p. 207) in his account of Protosiphon also noted the union of the gametes in threes especially when in organic solutions. The significance of these multiple fusions of swarm spores is not clear for we know nothing of the nuclear history following the union. There is in the habit, however, such a resemblance to the extensive union of swarmers in the Myxomycetes as to indicate that primarily sexuality may have been concerned chiefly with cytoplasmic fusions and associated very intimately with nutritive processes. I have recently observed several instances of the conjugation of zoöspores of Saprolegnia when the elements united in pairs at the ciliated ends and along the sides exactly as do motile gametes, and the fused cell bore four cilia. The zoöspores of Saprolegnia are too far removed morphologically from the highly differentiated sexual organs of the group to justify the explanation of such conjugation as a sexual act and we must think of it as due to some peculiarities of nutritive conditions.

Another class of very interesting cell fusions, associated with nutritive functions, is presented in the union of the sporophytic fertile filaments (oöblastema filaments) in the cystocarp of the Rhodophyceæ with auxiliary cells. This phenomenon which was regarded by Schmitz and his followers as sexual in charac-

ter, is considered by Oltmanns ('98b) to have nutritive relations alone. Oltmanns studied the fusion with auxiliary cells in several genera, but especially for Callithamnion and Dudresnaya, and is satisfied that the cell unions concern only the cytoplasm. Fertilization takes place with the fusion of gamete nuclei in the carpogonia and these cells develop the sporophyte generations. The fusion of fertilized carpogonia or filaments derived from them with auxiliary cells, is a feature of a sort of semiparasitic relation that the sporophyte holds to the gametophyte by which it is nourished in part through organic connections with the gametophyte. The nuclei of the sporophytic structures remain quite apart from those of the auxiliary cells so that the union is purely cytoplasmic. This theory of Oltmanns has received strong support through the detailed nuclear studies of Wolfe (:04) on fertilization and the development of the cystocarp of Nemalion who finds cytological evidence of the sporophytic character of the cystocarp. These papers of Oltmanns and Wolfe have been discussed by myself in the *Bot. Gaz.*, vol. 27, p. 314, 1899, and vol. 39, p. 64, 1905.

Writers have at times attached sexual significance to the conspicuous fusions between sporidia of certain of the Ustilaginales (*e. g.*, Tilletia). But there seems at present no reason to regard this phenomenon as different from the cytoplasmic connections frequently established between cells of hyphæ which are ultimately associated in a common mycelium where the whole forms a close unit with respect to common nutritive relations. Such protoplasmic connections were treated in the first part of this section. Harper ('99a) studied the union of conidia and cells of the promycelium in Ustilago and concluded that the fusions involve the cytoplasm alone, there being no nuclear changes. However, Federley (:03–:04; review in *Bot. Zeit.*, vol. 62, p. 171, 1904) has observed the migration of a nucleus from one conidium to another in *Ustilago tragopogonis pratensis* (Pers.), and a fusion within the latter. This nuclear fusion was not found in some other forms of Ustilago which behaved as Harper has described. There is nothing in the morphology of the conidia to indicate that they are sexual cells and from what we know of the life history of Basidiomycetes we should look

for sexual processes at other periods more closely associated with the development of teleutospores or basidia.

The conjugation of yeast cells has many points of similarity to the fusion of conidia in the Ustilaginales. This phenomenon has been discovered in an organism obtained from commercial ginger by Barker (:01), which he calls Zygosaccharomyces, and in three species of Schizosaccharomyces by Guilliermond (:03). The conjugation in all forms immediately precedes spore formation and involves a nuclear fusion as well as that of the cytoplasm. The conjugation is followed by division of the fusion nucleus and spore formation in the united cells. The conjugating cells are sisters in the species of Schizosaccharomyces but apparently may not be closely related in Barker's form, Zygosaccharomyces. Both investigators regard the conjugation as a sexual act, and Guilliermond considers the fusion cell to be an ascus with the value of a zygospore. These conclusions do not seem to the writer convincing. Spore formation in the yeasts has not been shown to present any of the peculiarities of nuclear division and free cell formation as described by Harper for the ascus, and until such are established it is hardly safe to conclude that the yeasts are Ascomycetes. Whether or not the conjugation is a sexual process becomes a question of phylogeny and we know too little of the history and relationships of the yeasts to assert that the conjugating cells are morphologically gametes. Again, the view that yeasts are derived from conidia or mycelia of higher fungi which have continued a simple growth by budding in peculiar and favorable media is rather against any view that we are dealing here with a simple or primitive sexual act. There are very striking resemblances to the fusions of conidia in the Ustilaginales, which were described in the previous paragraph and do not appear to be sexual processes. It is unsafe to assume sexuality because the conjugation precedes spore formation, because in most yeasts spore formation takes place regularly without conjugation. Is it not rather another illustration of cell and nuclear fusions related to nutritive processes alone?

Some of the most interesting nuclear fusions, apparently associated with the apogamous development of a sporophyte are

the unions of the pairs of nuclei which enter the cells of the developing teleutospores of the Uredinales and Ustilaginales and the basidium of higher Basidiomycetes. It has been established through the studies of a number of investigators (chiefly Rosen, '93; Dangeard and Sapin-Trouffy, '93; Dangeard '93, '94–'95a, c; Poirault and Raciborski, '95; Sapin-Trouffy, '96; Maire, :00 a, b, c, :02; Holden and Harper, :03) that the æcidiospores and the mycelium derived from them and preceding the development of the uredospores and teleutospores contain pairs of nuclei which divide in such a manner (conjugate division) that the nuclei of the pair are derived through two unbroken lines of succession for a long vegetative period and always maintain complete independence of one another. Every young teleutospore and basidium contains such a pair of nuclei which shortly fuse so that the mature structure is uninucleate. Dangeard and Sapin-Trouffy have from the first regarded the nuclear fusion within the teleutospore, whether of rust or smut, as a sexual act and the ripe teleutospore a fertilized egg, regardless of the fact that its morphology was not that of any known sexual organs. Dangeard ('94–'95 c; :00) likewise considered the nuclear fusions in the basidium as sexual. Raciborski ('96) suggested that the series of conjugate mitoses leading to the nuclear fusions in the teleutospore represented a vegetative phase intercalated between the beginning of a sexual act and its finish in the teleutospore. His explanation, in the light of the recent paper of Blackman (:04a), was nearest the truth. Maire (:02) presents the most extensive account of the nuclear structure in the higher Basidiomycetes previous to and during the formation of the basidia. He held that the fusion of the paired nuclei (synkaryon) in the basidium was not the whole act of fertilization which must begin with the formation of the paired nuclei. Maire (:02, p. 189) gave some suggestions as to how and where the paired nuclei arose but neither he nor any of the authors mentioned above knew clearly their origin.

Blackman (:04a) has made the most important contribution to the subject of fertilization and alternation of generation in the Uredinales, showing clearly that the paired nuclei appear in the life history of *Phragmidium violaceum* and *Gymnosporangium*

clavariæforme just before the development of the æcidium. They arise in Phragmidium by the migration of a nucleus from an adjacent cell into an element (the fertile cell) which represents a female sexual organ. The morphology of the female organ is not clear but there are suggestions of a structure similar to the procarps of the Rhodophyceæ and Laboulbeniales. The fertile cell, after receiving its second nucleus, develops a chain of æcidiospores, the two nuclei becoming so closely associated in the paired condition that they divide simultaneously (conjugate mitosis) from now on until the teleutospores are formed. Thus the cells of all mycelium beginning with the æcidiospore contain paired nuclei up to the development of the teleutospores, including of course the uredospores when present. This period of the life history may be considered as representing a sporophyte generation, especially since the total of chromatin in the pair of nuclei is double the amount when the nuclei are solitary. The sporophyte phase ends with the fusion of the pair of nuclei in each cell of the teleutospores and in the reduction phenomena that take place with the germination of the teleutospore, including the formation of the promycelium. The sporidia developed by the promycelium are uninucleate and the cells of the mycelium derived from them are uninucleate up to the production of the æcidium. This constitutes the gametophyte phase of the life history. The spermogonia by their morphology seem to be male organs, now functionless.

In such of the Uredinales as have no æcidium, as also in the higher Basidiomycetes and the Ustilaginales, it is probable that both sexual organs are suppressed since no trace of such structures has been found. However, we may expect to discover periods in all of these forms when paired nuclei come into the life history and after a series of conjugate divisions fuse in the teleutospore or basidium. Such pairs of nuclei, as stated before, are known in the Ustilaginales (Dangeard, '93) and in a number of forms of the Uredinales and the nuclear fusions have been followed in the teleutospore. Holden and Harper (:03) have given an especially clear account of the paired nuclei in the mycelium and uredospores of Coleosporium together with their fusion in the teleutospore. Maire (:02) describes the paired

nuclei (synkaryons) and their fusion in the basidium in a large number of Hymenomycetes and Gasteromycetes.

Evidence is thus accumulating that the cells in the mycelium of higher Basidiomycetes (Hymenomycetes and Gasteromycetes) are binucleate for extended periods previous to the formation of basidia where nuclear fusions always take place. Binucleate cells in the higher Basidiomycetes were first reported by Maire (: 00a ; : 00b), in the tissue preliminary to spore formation. He also confirmed Dangeard ('94–'95c) in his view that only two nuclei unite in the basidium contrary to accounts of Rosen ('93) and Wager ('99, p. 586) which described a succession of fusions involving sometimes as many as six or eight nuclei. Harper (: 02) has given for Hypochnus one of the most complete accounts of the behavior of paired nuclei previous to and during the development of the basidium. The cells of the mycelium of this simple Hymenomycete were found to be binucleate as far back as they were studied which included all of the conspicuous vegetative structure. Only a single pair of nuclei enters the basidium and fuses. Harper's results are then in agreement with the extended observations of Maire (: 02) as are also the detailed studies of Ruhland (: 01) on a number of forms and Bambeke (: 03). Taken together they seem to show clearly that the mycelium, for long periods preliminary to the formation of basidia, contains paired nuclei and that the basidia receive each a single pair, which nuclei fuse. There is thus an exact correspondence between the life histories of the Ustilaginales, Uredinales, and higher Basidiomycetes with respect to the period of paired nuclei and their fusion in the teleutospore or basidium. Dangeard called the fusion in the basidium a sexual act and the structure an oöspore regardless of the morphological difficulties of such a conception. Maire (: 02, p. 202) states that the origin of the paired nuclei is the only phenomenon strictly comparable to fertilization and Blackman's studies support this view. Ruhland (: 01) regards the conditions as a deviation from the normal type of sexuality calling it "intracellular karyogamy." The origin of the paired nuclei is not known for any higher Basidiomycete and the discovery of this period and determination of the events leading to the change from uninucleate mycelium to

binucleate is one of the most interesting problems in this field of botany. This is the point where we should expect to find the remains of sexual organs, if any are present in the higher Basidiomycetes, but it is not likely that they will be found. It seems more probable that the mycelium with the paired nuclei (perhaps sporophytic in character) arises apogamously with a complete suppression of the sexual organs in agreement with such of the Uredinales as have no æcidium and the Ustilaginales.

Blackman's explanation of the history of the paired nuclei in Phragmidium is full of interest. As stated before, he regards the fertile cell which develops a chain of æcidiospores, "as a female reproductive cell which undergoes a process of fertilization" by a union with an adjacent cell of the mycelium and its reception therefrom of a nucleus. The mycelium then which arises with the æcidiospore is sporophytic in character and so remains until the fusion of the pairs of nuclei in the teleutospores. The male organs of the rusts are the spermogonia and the male gametes the spermatia which are of course now functionless so that the "process of fertilization" is through the introduction into the female cell of a nucleus which is not phylogenetically a male sexual element. Blackman's (:04 a, pp. 349–353; :04 b) conception of the process as an act of fertilization involves some principles which will be briefly outlined.

Blackman believes for Phragmidium "that the primitive normal process of fertilization by means of spermatia has been replaced by fertilization of the female cell through the nucleus of an ordinary vegetative cell" and regards the process as very similar to the phenomenon reported in the apogamous development of ferns by Farmer, Moore, and Digby (:03), which will be considered presently. Blackman points out that normal processes of fertilization such as we have included under the head of "sexual cell unions and nuclear fusions" do not involve in many forms (probably all types with a sporophyte generation) an immediate union of the chromatin of the sexual nuclei which is known to remain distinct during the first cleavage mitosis in a number of types (*e. g.*, Pinus and some other gymnosperms). So there is nothing in the delayed fusion of the paired nuclei up to the teleutospore that is seriously against his explanation of the "fer-

tilization" of the female cell of the Uredinales. Indeed, we may expect to find that the actual fusion of paternal and maternal chromatin does not take place in the higher plants until the end of the sporophyte generation in the spore mother cell, as zoölogists have concluded that such union occurs just previous to gametogenesis in animals. But is Blackman justified in regarding the phenomenon substituted for the activities of ancestral sexual organs in Phragmidium, now functionless, as a sexual act and is it desirable to apply the term fertilization to the phenomenon?

Blackman (:04b, p. 153) speaks of the introduction of a nucleus into the fertile cell of the Uredinales and the phenomenon in the apogamous development of the fern after the account of Farmer, Moore, and Digby (:03) as "reduced forms of fertilization." It may be questioned whether the use of the term fertilization is fully justified by the events under discussion. We are all likely to agree with these authors that the physiological aspects of the phenomena in the cases under consideration are similar to sexual acts. But, by the writer, the act of fertilization is always considered in phylogenetic relations and strictly limited to the union of sexually differentiated cells, which are defined by their morphology through principles of homology. Whenever one or both of the gametes are suppressed in a life history and a succeeding generation develops of the sort that normally follows a sexual act, then such a development is apogamous and the phenomena always introduce features which are foreign to the processes of normal fertilization and the fundamental principles of sexuality.

Perhaps the most important characteristic of sexuality from an evolutionary standpoint is the fusion of gametes of unrelated parentage, for in the mingling of diverse protoplasm lie two factors: (1) a physiological stimulus to development, and (2) an increased probability of inherited variation which in new combinations will appear to the advantage of the species. Blackman's "reduced forms of fertilization" which I should prefer to consider apart from normal fertilization as examples of apogamy, and have so classed in this treatment, do satisfy the physiological requirements of a sexual act in that a form of nuclear fusion

is substituted for the union of gamete nuclei but the phylogenetic and evolutionary aspects of sexuality are disregarded. Also, the nuclei that fuse are sometimes very closely related, which is a condition generally avoided in sexual processes except where peculiarities of habit make close inbreeding necessary. It is true that large groups, such as the Basidiomycetes, perhaps certain regions of the Ascomycetes, some Phycomycetes, and some forms of the higher plants and algæ seem to have given up normal sexual processes but there is much evidence that in many cases this loss of sexuality is associated with a certain degree of segregation and with peculiarities of life conditions apart from the normal activities of all organisms or quite different from the ancestral stock. The groups are likely to be distinguished by highly specialized life habits of a sort that make it impossible for inherited sexual organs to function, either through mechanical difficulties or because one or both degenerate. It seems to me much clearer to regard all illustrations of Blackman's "reduced forms of fertilization" under the general term of apogamy even though it may be clear that they are physiological substitutes for sexual acts and to reserve the term fertilization for the union of gametes which can always be clearly identified through morphology in ontogeny and phylogeny. The success of a group even though ancestral sexual processes may be suppressed does not enter into a problem which is at bottom a morphological one. Success is relative and we really have no means of estimating its degree save by actual experiment. It is not likely that any biologist would claim that sexual degeneration is advantageous to any species although the organic world is full of forms which have dispensed with sexuality and still hold their places. These are the reasons why I have grouped cell unions and nuclear fusions as sexual and asexual on a morphological basis founded on phylogenetic principles and why in Section V, we shall devote some attention to the substitutes for sexuality under the head of apogamy.

The Ascomycetes present a phenomenon of nuclear fusion within the ascus which may properly be considered at this time since there is a certain resemblance to the nuclear fusions in the teleutospore and basidium. Dangeard ('94–'95b) gave the

first account of this phenomenon describing it for several forms. The mother cell of an ascus sometimes terminates a hypha but more commonly is situated a little back from the end at a point where the hypha bends abruptly like a knee. The mother cell contains two nuclei, closely related to each other, that unite, after which the fusion nucleus divides to form the ascospores. Dangeard considered this fusion to be a sexual act and the product an oöspore which germinates immediately to form the ascus. He regards the ascus as a sporangium, and equivalent to the promycelium which he calls a conidiophore. Dangeard is not willing to accept any of the evidence that the ascocarp ever results from a sexual act or that sexual organs either functional or abortive are present at any stage in the life history of Ascomycetes. Sexuality, according to him, is reduced to the fusion within the ascus alone. He (Dangeard, '96–'97a, b; :00) discredits the work of Harper on Sphærotheca, Erysiphe, and Pyronema and the older accounts of De Bary and his pupils on sexual organs of the Ascomycetes. A series of short papers in *Le Botaniste* (:03, Fas. 1) presents Dangeard's last attack on the work of Harper and a reaffirmation of his peculiar views.

Harper's description of sexual processes in Sphærotheca ('95; '96) Erysiphe ('96), and Pyronema (:00b) are so convincing that, together with our knowledge of sexual organs in the lichens, Laboulbeniales, and Gymnoascales, we must accept the old view of De Bary that the ascocarp represents a development (probably sporophytic) from a sexual phase even though it may be established that there is much apogamy in the Ascomycetes. Harper gives the clearest account of the nuclear fusion in the ascus of any author without, however, committing himself to speculations on its significance. The subject is well summarized in his paper on Pyronema (:00b, pp. 363, 394). He finds in Erysiphe, Pyronema, and some other forms that the ascus is always developed from a penultimate cell of a hypha which bends sharply so that this cell appears to lie at the tip. There are two nuclei at the end of the ascogenous hypha and these divide simultaneously in a very characteristic manner so that the young ascus receives two of the resultant four nuclei, but each is derived from a different one of the original pair and

consequently they are not sisters. The two nuclei in the ascus then fuse. The origin of the original pair is not known.

No satisfactory explanation of this fusion in the ascus has been advanced. The conditions in the Ascomycetes are not the same as in the Basidiomycetes. There is no series of paired nuclei in the ascogenous hyphæ and no evidence of a delayed fusion of gamete nuclei following a sexual act nor of nuclear fusions associated with the apogamous development of a sporophyte generation. On the contrary, a sexual act with the fusion of gamete nuclei has been clearly established in some forms preliminary to the development of the ascocarp and the nuclear union in the ascus is plainly a supplementary phenomenon. Wager and Harper point out analogies to the account of Chmielewski ('90b) for Spirogyra, considered in a previous part of this section, which described a double nuclear fusion in the zygospore. Thus the primary, sexually formed nucleus of the zygospore is reported to divide into four secondary nuclei, two of which break down while the remaining two unite forming the second and final fusion nucleus of the spore. It is hard to see how these second nuclear fusions can be sexual and Groom ('98) is perhaps correct in considering them superimposed on the sexual act, but their physiological significance is not clear.

Some recent papers support in general Harper's investigations on the ascus. Guilliermond (:04a; :04b) describes the development of the ascus and ascospores in a number of forms. In an unnamed species of Peziza he found, however, that the ascus developed from the terminal cell of the ascogenous hypha which received two nuclei (that fuse) of the four that are found at the tip. Maire (:03a; :03b) has reported a similar history for *Galactinia succosa*. Both Maire and Guilliermond note the resemblance of these conditions to the nuclear associations in the young basidium and Maire does not hesitate to consider the two nuclei in the tip of the ascogenous hypha as much reduced synkaryons, (paired nuclei) appearing for a very short period just previous to the nuclear fusions in the ascus. Maire follows Dangeard in denying the sexual processes described by Harper in the Ascomycetes and would allign the events in the ascus with those in the basidium. Guilliermond agrees with

Harper that the number of chromosomes presented in the mitoses within the ascus is large (8, 12, 16, in various species) as against Dangeard and Maire who have claimed that the number is uniformly 4. Guilliermond's account of spore formation in the ascus supports that of Harper (described in Section II) in all essentials and gives especial attention to the structure of the epiplasm and its inclusions.

In summary: the significance of the nuclear fusions in the ascus seems very much of a mystery. If they could be associated with an apogamous development of the ascocarp we should have conditions analogous to those in the Basidiomycetes but following a sexual act as it does in Sphærotheca, Erysiphe, and Pyronema we find a phenomenon whose *raison d' être* is not apparent. However, we do not know the history of the nuclei preceding the group of four at the end of the ascogenous hypha and perhaps it may be discovered that events at this period are concerned with nuclear reduction at the end of a sporophyte generation.

One of the most interesting announcements of recent months is that in a preliminary note of Farmer, Moore, and Digby (:03) on the nuclear history preceding the apogamous development of a species of Nephrodium. They found that the cells of the prothallus at the point where the sporophyte arose became binucleate by the migration of nuclei from neighboring cells. The two nuclei might remain separate for some time or fuse at once. The authors speak of the whole process "as a kind of irregular fertilization" and Blackman considers it analogous to the entrance of the nucleus into the fertile cell of Phragmidium and the establishment of the paired nuclei in the Uredinales. As we discussed the phenomenon in that connection I considered the use of the term fertilization unfortunate since it included processes which however similar physiologically held no relation morphologically and phylogenetically to normal sexual processes. As stated then, it seems to me much clearer to regard all such apogamous phenomena apart from sexual processes, pointing out as far as possible physiological resemblances but recognizing the wide gap in morphology established by the past evolutionary history of the plant. The interest in the phe-

nomena does not become less by this treatment which certainly avoids much confusion of expression.

There is left for consideration one other group of nuclear fusions which may have sexual significance although such is not obvious, namely the fusions of polar nuclei in the embryo sac of angiosperms and the triple unions of the above with a second sperm nucleus which is often called "double fertilization." Several excellent reviews of this subject have appeared, notably by Strasburger (:00b), Sargant (:00), Coulter and Chamberlain (:03), Mottier (:04a, b), and Guérin (:04). The explanation of this phenomenon is likely to rest finally upon morphological analysis but at present we are uncertain of the homologies of the polar nuclei and the part they play in the evolutionary history of the endosperm. The most striking theory of the endosperm was proposed by LeMonnier ('87) who suggested that the fusion of the polar nuclei gave origin to a second embryo modified to nourish the normal embryo. One of the polar nuclei is always closely related to the egg nucleus so that in the triple fusions (the sperm with two polar nuclei) we have conditions very close to normal fertilization, the discordant element being not the sperm nucleus but the antipodal polar nucleus. The triple fusions would seem at first thought to be rather favorable to LeMonnier's theory although it is plain that with such a diverse mixture of chromatin from three nuclei the resultant structure can scarcely be called a sporophyte embryo from the very grotesqueness of its make-up. Miss Sargant considers the fusion of the second sperm with the micropylar nucleus as sexual in character but so complicated by the introduction of the antipodal polar nucleus that the result is a bizarre structure not strictly comparable to a normal embryo. In the final solution of this problem we must know whether in phylogeny the sperm and micropylar polar nucleus fused first and the antipodal entered into the process later or whether the polar nuclei began the habit and the second sperm nucleus was drawn afterwards into the activities. Should the first possibility be established the sexual nature of the process would seem clear while in the second the events would be of the nature of asexual nuclear fusions. While we know very little

of the origin and evolution of the endosperm in angiosperms there is some evidence in favor of the second possibility.

Strasburger (:oob) holds that the double and triple nuclear fusions in the embryo sac are not true sexual acts even though they may involve an important principle of fertilization, namely, a stimulus to growth. According to him, sexual processes present two distinct features which he designates as "generative fertilization" and "vegetative fertilization." Generative fertilization deals with the mingling of ancestral hereditary substances in the nuclei and establishes the basis for such characters as hold the species true to its past or introduce new qualities as variations into the germ plasm. Vegetative fertilization brings to the fusion nucleus simply a stimulus to growth such as may be given to unfertilized eggs by changes in their physical and chemical environment. We might apply this classification to many of the examples of asexual nuclear fusions which we have discussed, as in the apogamous development of the fern and the origin of the paired nuclei in the rusts, and they have the elements of vegetative fertilization in Strasburger's sense. But such distinctions are very subtle and it seems rather doubtful whether they add much to the clearness of our conceptions. The growth stimulus of "vegetative fertilization" is always an accompaniment of "generative fertilization" and would be expected of any cell unions or nuclear fusions. The peculiarities of sex lie in the phylogenetic features of the phenomena, *i. e.*, in the union of differentiated gametes with their long evolutionary history and not in the mere fusion of any nuclei at any time.

From this point of view the double fusions of polar nuclei or the triple fusions, when a sperm nucleus becomes involved in the phenomenon, are of very doubtful sexual nature since no phylogenetic connections have been established with the normal sexual processes of the spermatophytes. Indeed, there are many irregularities in the process of endosperm formation which complicate the discussion and make it very difficult to trace relationships. Thus nuclear fusions are described in the late stages of endosperm formation when several of the free nuclei become included in the same cell area by the formation of the cell walls

(Corydalis, Strasburger, '80; Tischler, :00; Canna, Humphrey, '96). Such nuclei are known to unite two or more and sometimes several together within the cells, forming fusion nuclei with a large and variable number of chromosomes. In Peperomia and Gunnera the endosperm nucleus results from the fusion of several free nuclei and a number of instances are recorded in which no fusion of the polar nuclei takes place, but the endosperm is derived from the division of one or both. Such irregularities, which will probably be greatly increased in number as investigations proceed, indicate that the double and triple fusions preceding the differentiation of the endosperm nucleus are not of phylogenetic importance but are more likely to be special developments in relation to peculiarities of seed formation among the angiosperms rather than of a sexual nature.

However, the triple fusions, when a sperm enters into the composition of the endosperm nucleus, seem to furnish a cytological explanation of the phenomenon of xenia and thus come into very close physiological relations to sexual processes. In xenia we find the effects of hybridization expressed immediately outside of the embryo in the endosperm of the seeds. If paternal chromatin has entered into the composition of the endosperm nucleus or should the sperm nucleus by itself give rise to a series of endosperm nuclei the appearance of paternal characters would be expected. This explanation of xenia was worked out independently by DeVries, Correns, and Webber, the last author having published a particularly clear and full account of the phenomenon (Webber, :00). Even though the relation of xenia to hybridization is apparent, it is nevertheless clear that we are dealing with an exceptional process only possible because of the unusual conditions within the embryo sac which allow a second sperm nucleus to enter into the activities of seed formation and it is certainly not established that these activities have any phylogenetic relations to past sexual processes.

Some interesting studies of Nemec (:02–:03; :04) upon asexual nuclear fusions may open the way for explanations of some of the examples which we have considered as asexual in the latter portion of this paper. Nemec found that mitosis in the root tip of *Pisum sativum* could be checked during anaphase

by treating the material with chloral hydrate so that no walls were formed between the daughter nuclei, which remained in the common mother cell and presently fused with one another. The fusion nucleus presented a double number of chromosomes (twice that of the normal sporophyte) in succeeding mitoses which became reduced in a few hours so that later divisions showed the number characteristic of the sporophyte. Nemec regards nuclear fusions and reduction phenomena as self regulating processes which follow the vital cell fusions characteristic of fertilization. The latter (cell fusions) are then the essential phenomena of sex and nuclear activities follow automatically. Reduction phenomena are atavistic in character. Nemec considers these results in serious conflict with Strasburger's ('94) theory of the periodic reduction of the chromosomes, believing that the number of chromosomes is not so likely to give the characters of the respective sporophyte and gametophyte generations as other factors.

Nemec's contribution is chiefly of interest to us in the present connection as showing that nuclear fusions may result from disturbances of the normal environment very far removed from the conditions that produce sexual cells. And this emphasizes our contention that sexual processes must be judged through phylogenetic analysis and not by physiological resemblances. Thus the nuclear fusions in the ascus, in the basidium, preceding apogamous development of the fern, and perhaps the union of polar nuclei in the embryo sac may be involved with special physiological conditions although they resemble outwardly sexual processes and are sometimes a substitute for these. But nevertheless they are asexual nuclear fusions lacking that fundamental character of sexuality, the result of sexual evolution, namely, a fixed position in a life cycle established by phylogeny and expressed by the classic phrase "ontogeny repeats phylogeny." They are departures from the normal life history either apogamous in character or concerned with some other peculiarity of the plants' existence.

LITERATURE CITED IN SECTION IV, "THE PLANT CELL."

BAMBEKE.

:03. Sur l'evolution nucléaire et la sporulation chez *Hydnangium carneum* Wallr. Mem. d. l'Acad. Roy. Sci., Litt., Beaux Arts d. Belgique, vol. 54.

BARKER.

:01. A Conjugating Yeast. Phil. Trans. Roy. Soc. London, vol. 194, p. 467.

BERTHOLD.

'81. Die geschlechtliche Fortpflanzung der eigentlichen Phæospo reen Mitt. a. d. Zoöl. Sta. Neapel, vol. 2, p. 401.

BLACKMAN.

'98. The Cytological Features of Fertilization and related Phenomena in *Pinus sylvestris* L. Phil. Trans. Roy. Soc. London, vol. 190, p. 395.

BLACKMAN.

:04a. On the Fertilization, Alternation of Generations and General Cytology of the Uredineæ. Annals of Bot., vol. 18, p. 323.

BLACKMAN.

:04b. On the Relation of Fertilization to "Apogamy" and "Parthenogenesis." New Phytologist, vol. 3, p. 149.

CHAMBERLAIN.

'99. Oögenesis in *Pinus laricio.* Bot. Gazette, vol. 27, p. 268.

CHMIELEWSKI.

'90a. Eine Notiz über das Verhalten der Chlorophyllbänder in den Zygoten der Spirogyren-Arten. Bot. Zeit., vol. 48, p. 773.

CHMIELEWSKI.

'90b. Materialien zur Morphologie und Physiologie des Sexualprocessen bei den niederen Pflanzen. (Russian.) Review, Bot. Centralbl., vol. 50, p. 264.

COKER.

:03. On the Gametophytes and Embryo of Taxodium. Bot. Gazette, vol. 36, p. 114.

COULTER and CHAMBERLAIN.

:03. Morphology of the Angiosperms. New York, 1903.

DANGEARD.

'93. La reproduction sexuelle des Ustilaginées. Compt. Rendus, vol. 117, p. 496.

DANGEARD.

'94–'95a. La reproduction sexuelle de *l'Entyloma Glaucii.* Le Botaniste, vol. 4, p. 12.

DANGEARD.
'94–'95b. La reproduction sexuelle des Ascomycètes. Le Botaniste, vol. 4, p. 21.
DANGEARD.
'94–'95c. Mémoire sur la reproduction sexuelle des Basidiomycètes. Le Botaniste, vol. 4, p. 119.
DANGEARD.
'96–'97a. La reproduction sexuelle dans le *Sphærotheca Castagnei*. Le Botaniste, vol. 5, p. 27.
DANGEARD.
'96–'97b. Second mémoire sur la reproduction sexuelle des Ascomycètes. Le Botaniste, vol. 5, p. 245.
DANGEARD.
:00. La reproduction sexuelle des champignons. Le Botaniste, vol. 7, p. 89.
DANGEARD et SAPIN–TROUFFY.
'93. Une pseudofécondation chez les Uredinées. Compt. Rendus, vol. 117, p. 267.
DAVIS.
'96b. Development of the Cystocarp of *Champia parvula*. Bot. Gazette, vol. 21, p. 109.
DAVIS.
:00. The Fertilization of *Albugo candida*. Bot. Gazette, vol. 29, p. 297.
DAVIS.
:01. The Origin of Sex in Plants. Pop. Sci. Month., vol. 60, p. 66.
DAVIS.
:03. The Evolution of Sex in Plants. Pop. Sci. Month., vol. 62, p. 300.
DAVIS.
:04. Oögenesis in Vaucheria. Bot. Gazette, vol. 38, p. 81.
DE BARY and STRASBURGER.
'77. *Acetabularia mediterranea*. Bot. Zeit., vol. 35, p. 713.
FAIRCHILD.
'97. Ueber Kerntheilung und Befruchtung bei *Basidiobolus ranarum* Eidam. Jahrb. f. wiss. Bot., vol. 30, p. 285.
FARMER, MOORE, and DIGBY.
:03. On the Cytology of Apogamy and Apospory. I. Preliminary Note on Apogamy. Proc. Roy. Soc. London, vol. 71, p. 453.
FARMER and WILLIAMS.
'98. Contributions to our Knowledge of the Fucaceæ; their Life History and Cytology. Phil. Trans. Roy. Soc. London, vol. 190, p. 623.
FEDERLEY.
:03–:04. Die Copulation der Conidien bei *Ustilago Tragopogonis pratensis* Pers. Finska Veten. Selsk. Forhandl., vol. 46, no. 2.

FERGUSON.

:04. Contributions to the Knowledge of the Life History of Pinus with Special Reference to Sporogenesis, the Development of the Gametophytes and Fertilization. Proc. Wash. Acad. Sci., vol. 6, p. 1.

GARDINER.

'88. On the Continuity of Protoplasm through the Walls of Vegetable Cells. Arb. d. bot. Inst. Würzb., vol. 3, p. 52.

GARDINER.

'98. The Histology of the Cell Wall with Special Reference to the Mode of Connections of the Cells. Proc. Roy. Soc. London, vol. 62, p. 100.

GARDINER.

:00. The Genesis and Development of the Wall and Connecting Threads in the Plant Cell. Proc. Roy. Soc. London, vol. 66, p. 186.

GOLENKIN.

'99. Ueber die Befruchtung bei *Sphæroplea annulina* und über die Structur der Zellkerne bei einigen grünen Algen. Bull. Soc. Imp. Nat. Moscow, 1899, p. 343.

GOROSCHANKIN.

'83. Zur Kenntniss der Corpuscula bei den Gymnospermen. Bot. Zeit., vol. 41, p. 825.

GROOM.

'98. On the Fusion of Nuclei among Plants. Trans. and Proc. Bot. Soc. Edinburgh, 1898.

GUÉRIN.

:04. Les connaissances actuelles sur la fécondation chez les phanérogams. Paris, 1904.

GUILLIERMOND.

:03. Recherches cytologiques sur les levure. Rev. Gen. d. Bot., vol. 15, pp. 49, 104, 166.

GUILLIERMOND.

:04a. Contribution à l'étude de la formation des asques et de l'epiplasme des Ascomycètes. Rev. Gen. d. Bot., vol. 16, p. 49.

GUILLIERMOND.

:04b. Recherches sur la karyokinèse chez les Ascomycètes. Rev. Gen. d. Bot., vol. 16, p. 129.

HARPER.

'95. Die Entwickelung des Peritheciums bei *Sphærotheca Castagnei.* Ber. deutsch. bot. Gesellsch., vol. 13, p. 475.

HARPER.

'96. Ueber das Verhalten der Kerne bei der Fruchtentwickelung einiger Ascomyceten. Jahrb. f. wiss. Bot., vol. 29, p. 655.

HARPER.

'99a. Nuclear Phenomena in certain Stages of Development of the Smuts. Trans. Wisc. Acad. Sci., Arts, Lett., vol. 12, p. 475.

HARPER.

:**02**. Binucleate Cells in certain Hymenomycetes. Bot. Gazette, vol. 33, p. 1.

HARPER.

:**00**. Sexual Reproduction in *Pyronema confluens* and the Morphology of the Ascocarp. Annals of Bot., vol. 14, p. 321.

HAUPTFLEISCH.

'**88**. Zellmembran und Hüllgallerte der Desmidiaceen. Mitt. a. d. naturwiss. Ver. f. Neu-Vor. u. Rügen, 1888.

HAUPTFLEISCH.

'**95**. Die Ortsbewegung der Bacillariaceen. Mitt. a. d. naturwiss. Ver. f. Neu-Vor. u. Rügen, vol. 27.

HILL.

:**01**. The Histology of the Sieve-tubes of Pinus. Annals of Bot., vol. 15, p. 575.

HOLDEN and HARPER.

:**03**. Nuclear Division and Nuclear Fusion in *Coleosporium sonchi-arvensis* Lev. Trans. Wisc. Acad. Sci., Arts, Lett., vol. 14, p. 63.

HUMPHREY.

'**96**. The Development of the Seed in Scitamineæ. Annals of Bot., vol. 10, p. 1.

IKENO.

'**98b**. Untersuchungen über die Entwickelung der Geschlechtsorgane und den Vorgang der Befruchtung bei *Cycas revoluta*. Jahrb. f. wiss. Bot., vol. 32, p. 557.

IKENO.

:**01**. Contribution a l'étude de la fécondation chez le *Ginkgo biloba*. Ann. Sci. Nat., Bot., ser. 8, vol. 13, p. 305.

IKENO.

:**04**. Blepharoplasten im Pflanzenreich. Biol. Centralbl., vol. 24, p. 211.

KARSTEN.

:**00**. Die Auxosporenbildung der Gattungen Cocconeis, Surirella, und Cymatopleura. Flora, vol. 87, p. 253.

KIENITZ-GERLOFF.

'**91**. Die Protoplasmaverbindungen zwischen benachbarten Gewebselementen in der Pflanze. Bot. Zeit., vol. 49, pp. 17, 33, 49, 65.

KIENITZ-GERLOFF.

:**02**. Neue Studien über Plasmodesmen. Ber. deutsch. bot. Gesellsch., vol. 20, p. 93.

KING.

:**03**. Observations on the Cytology of *Araiospora pulchra* Thaxter. Proc. Boston Soc. Nat. Hist., vol. 31, p. 211.

KLEBAHN.

'**91**. Studien über Zygoten. I. Die Keimung von Closterium und Cosmarium. Jahrb. f. wiss. Bot., vol. 22, p. 415.

KLEBAHN.
'92. Studien über Zygoten. II. Die Befruchtung von *Œdogonium Boscii.* Jahrb. f. wiss. Bot., vol. 24, p. 235.

KLEBAHN.
'96. Beiträge zur Kenntniss der Auxosporenbildung. I. *Rhopalodia gibba* (Ehrenb.) O. Müller. Jahrb. f. wiss. Bot., vol. 29, p. 595.

KLEBAHN.
'99. Die Befruchtung von *Sphæroplea annulina* Ag. Festsch. f. Schwendener, p. 81, 1899.

KLEBS.
'96. Die Bedingungen der Fortpflanzung bei einigen Algen und Pilzen. Jena, 1896.

KNY.
:04. Studien über intercellularen Protoplasma. Ber. deutsch. bot. Gesellsch., vol. 22, pp. 29, 347.

KOENICKE.
:01. Ueber Ortsveränderungen von Kernen. Sitz. niederrh. Gesellsch. f. Nat. u. Heilk. z. Bonn, 1901, p. 14.

KOENICKE.
:04. Der heutige Stand der pflanzlichen Zellforchung. Ber. deut. bot. Gesellsch., vol. 21, p. 66.

KOHL.
'91. Protoplasmaverbindungen bei Algen. Ber. deutsch. bot. Gesellsch., vol. 9, p. 9.

KOHL.
'97. Die Protoplasmaverbindungen der Spaltöffnungsschliesszellen und der Moosblattzellen. Bot. Centralbl., vol. 72, p. 257.

KOHL.
:00. Dimorphism der Plasmaverbindungen. Ber. deutsch. bot. Gesellsch., vol. 18, p. 364.

KOHL.
:02. Beiträge zur Kenntniss der Plasmaverbindungen in den Pflanzen. Beiheft z. Bot. Centralbl., vol. 12, p. 343.

KRUCH.
'90. Appunti sullo sviluppo degli organi sessuali e sulla fecondazione della *Riella clausonis* Let. Malpighia, vol. 4, p. 403.

KUCKUCK.
'98. Ueber die Paarung von Schwarmsporen bei Scytosiphon. Ber. deutsch. bot. Gesellsch., vol. 16, p. 35.

KUHLA.
:00. Die Plasmaverbindungen bei *Viscum album.* Bot. Zeit., vol. 58, p. 29.

LAND.
:02. A Morphological Study of Thuja. Bot. Gazette, vol. 34, p. 249.

LAWSON.
:04a. The Gametophytes, Archegonia, Fertilization and Embryo of *Sequoia sempervirens.* Annals of Bot., vol. 18, p. 1.
LAWSON.
:04b. The Gametophytes, Fertilization and Embryo of *Cryptomeria japonica.* Annals of Bot., vol. 18, p. 417.
LEMONNIER.
'87. Sur la valeur morphologique de l'albumen chez les angiospermes. Journ. d. Bot., vol. 1, p. 140.
MAIRE.
:00a. Sur la cytologie des Hymenomycètes. Compt. Rendus, vol. 131, p. 121.
MAIRE.
:00b. Sur la cytologie des Gasteromycètes. Compt. Rendus, vol. 131, p. 1246.
MAIRE.
:00c. L'évolution nucléaire chez les Endophyllum. Journ. d. Bot., vol. 14, p. 80.
MAIRE.
:02. Recherches cytologiques et taxonomiques sur les Basidiomycètes. Bull. Soc. Mycol. d. France, vol. 18.
MAIRE.
:03a. Recherches cytologiques sur le *Galactinia succosa.* Compt. Rendus de l'Acad. Sci. Paris, Nov. 9, 1903.
MAIRE.
:03b. La formation des asques chez les Pezizes et l'évolution nucléaire des Ascomycètes. Compt. Rendus d. Séan. d. l. Soc. Biol., vol. 55, p. 1401.
MEYER.
'96. Die Plasmaverbindungen und die Membranen von *Volvox globator*, *aureus* und *tertius* mit Rucksicht auf die tierischen Zellen. Bot. Zeit., vol. 54, p. 187.
MEYER.
:02. Die Plasmaverbindungen und die Fusionen der Pilze der Florideenreihe. Bot. Zeit., vol. 60, p. 139.
MICHNIEWICZ.
:04. Ueber Plasmodesmen in den Kotyledonen von Lupinus-Arten und ihre Beziehung zum interzellularen Plasma. Oester. bot. Zeitsch., vol. 54, p. 165.
MIEHE.
:01. Ueber die Wanderungen des pflanzlichen Zellkernes. Flora, vol. 88, p. 105.
MIYAKE.
:01. The Fertilization of *Pythium deBaryanum.* Annals of Bot., vol. 15, p. 653.

MIYAKE.

:**03a**. On the Development of the Sexual Organs in *Picea excelsa.* Annals of Bot., vol. 17, p. 351.

MIYAKE.

:**03b**. Contribution to the Fertilization and Embryogeny of *Abies balsamea.* Beiheft z. Bot. Centralbl., vol. 14, p. 134.

MOENKHAUS.

:**04**. The Development of the Hybrids between *Fundulus heteroclitus* and *Menedia notata* with especial Reference to the Behavior of the Maternal and Paternal Chromosomes. Amer. Journ. of Anat., vol. 3, p. 29.

MONTGOMERY.

:**01**. A Study of the Germ Cells of Metazoa. Trans. Amer. Phil. Soc., vol. 20, p. 154.

MOTTIER.

'98. Ueber das Verhalten der Kerne bei der Entwickelung des Embryosacks und die Vorgänge bei der Befruchtung. Jahrb. f. wiss. Bot., vol. 31, p. 125.

MOTTIER.

:**04a**. The Development of the Spermatozoid in Chara. Annals of Bot., vol. 18, p. 245.

MOTTIER.

:**04b**. Fecundation in Plants. Carnegie Inst. Washington, 1904.

MÜLLER.

'98–'99. Kammern und Poren in der Zellwand der Bacillariaceen. I, II. Ber. deutsch. bot. Gesellsch., vol. 16, p. 386; vol. 17, p. 432.

MURRILL.

:**00**. The Development of the Archegonium and Fertilization in the Hemlock Spruce (*Tsuga Canadensis* Carr.) Annals of Bot., vol. 14, p. 583.

NEMEC.

:**02**–:**03**. Ueber ungeschlechtliche Kernverschmeltzungen. I, II, III. Sitz. kön. böhm. Gesellsch. Wiss., 1902–03.

NEMEC.

:**04**. Ueber die Einwirkung des Chloralhydrats auf die Kern- und Zelltheilung. Jahrb. f. wiss. Bot., vol. 39, p. 645.

OLTMANNS.

'95. Ueber die Entwickelung der Sexualorgane bei Vaucheria. Flora, vol. 80, p. 388.

OLTMANNS.

'98a. Die Entwickelung der Sexualorgane bei *Coleochæte pulvinata.* Flora, vol. 85, p. 1.

OLTMANNS.

'98b. Zur Entwickelungsgeschichte der Florideen. Bot. Zeit., vol. 56, p. 99.

OLTMANNS.
'99. Ueber der Sexualität der Ectocarpeen. Flora, vol. 86, p. 86.
OSTERHOUT.
:00. Befruchtung bei Batrachospermum. Flora, vol. 87, p. 109.
POIRAULT and RAČIBORSKI.
'95. Sur le noyau des Urédinées. Journ. d. Bot., vol. 9, p. 318.
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'96. Ueber den Einfluss äusserer Bedingungen auf die Wachstumsweise des *Basidiobolus ranarum*. Flora, vol. 82, p. 107.
REINHARDT.
'92. Das Wachstum der Pilzhyphen. Jahrb. f. wiss. Bot., vol. 23, p. 479.
ROBERTSON.
:04. Studies in the Morphology of *Torreya californica* Torrey. II. The Sexual Organs and Fertilization. New Phytologist, vol. 3, p. 205.
ROSEN.
'93. Studien über die Kerne und die Membranbildung bei Myxomyceten und Pilzen. Cohn's Beitr. z. Biol. d. Pflan., vol. 6, p. 237.
ROSTAFINSKI und WORONIN.
'77. Ueber *Botrydium granulatum*. Bot. Zeit., vol. 35, p. 649.
RUHLAND.
:01. Zur Kenntniss der intracellularen Karyogamie bei den Basidiomyceten. Bot. Zeit., vol. 59, p. 187.
RUSSOW.
'83. Ueber den Zusammenhang der Protoplasmakörper benachbarter Zellen. Sitz. dorpater naturf. Gesellsch., 1883.
SAPPIN-TROUFFY.
'96. Recherches histologiques sur la famille des Urédinées. Le Botaniste, vol. 5, p. 59.
SARGANT.
:00. Recent Work on the Results of Fertilization in Angiosperms. Annals of Bot., vol. 14, p. 689.
SCHMIDLE.
'99. Einiges über die Befruchtung, Keimung und Haarinsertion von Batrachospermum. Bot. Zeit., vol. 57, p. 125.
SCHRAMMEN.
:02. Ueber die Einwirkung von Temperaturen auf die Zellen des Vegetationspunktes des Sprosses von *Vicia foba*. Verhand. d. naturhist. Vereins d. preuss. Rheinlande, vol. 59.
SCHUTT.
'99. Centrifugales Dickenwachstum der Membran und extramembranoses Plasma. Jahrb. f. wiss. Bot., vol. 33, p. 594.

SCHUTT.

:00a. Die Erklärung des centrifugalen Dickenwachstum der Membran. Bot. Zeit., vol. 59, p. 245.

SCHUTT.

:00b. Centrifugale und simultane Membranverdickungen. Jahrb. f. wiss. Bot., vol. 35, p. 470.

SHAW.

'98a. The Fertilization of Onoclea. Annals of Bot., vol. 12, p. 261.

SMITH.

:00. The Haustoria of the Erysipheæ. Bot. Gazette, vol. 29, p. 153.

SMITH, ISABEL.

:04. The Nutrition of the Egg in Zamia. Bot. Gazette, vol. 37, p. 346.

STEVENS.

'99. The Compound Oösphere of *Albugo bliti*. Bot. Gazette, vol. 28, p. 149.

STEVENS.

:01b. Gametogenesis and Fertilization in Albugo. Bot. Gazette, vol. 32, p. 77.

STRASBURGER.

'80. Zellbildung und Zelltheilung. Jena, 1880.

STRASBURGER.

'82. Ueber den Bau und Wachsthum der Zellhaüte. Jena, 1882.

STRASBURGER.

'94. The Periodic Reduction of the Number of Chromosomes in the Life History of Living Organisms. Annals of Bot., vol. 8, p. 281.

STRASBURGER.

'97a. Kerntheilung und Befruchtung bei Fucus. Jahrb. f. wiss. Bot., vol. 30, p. 351.

STRASBURGER.

:00b. Einige Bemerkungen zur Frage nach der doppleten Befruchtung bei den Angiospermen. Bot. Zeit., vol. 58, p. 293.

STRASBURGER.

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SUTTON.

:02. On the Morphology of the Chromosome Group in *Brachystola magna*. Biol. Bull., vol. 4, p. 24.

SUTTON.

:03. The Chromosomes in Heredity. Biol. Bull., vol. 4, p. 231.

TANGL.

'79–'81. Ueber offene Communicationen zwischen den Zellen des Endosperms einiger Samen. Jahrb. f. wiss. Bot., vol. 12, p. 170.

TERNETZ.

:00. Protoplasmabewegung und Fruchtkörperbildung bei *Ascophanus carneus*. Jahrb. f. wiss. Bot., vol. 35, p. 273.

THAXTER.
'**96**. Contribution towards a Monograph of the Laboulbeniaceæ. Mem. Amer. Acad. Arts and Sci., vol. 12.

THOM.
'**99**. The Process of Fertilization in Aspidium and Adiantum. Trans. Acad. Sci. St. Louis, vol. 9, p. 285.

TISCHLER.
:**00**. Untersuchungen über die Entwickelung des Endosperm und der Samenschale von *Corydalis cava.* Verh. naturhist.-med. Ver. Heidelberg, vol. 6, p. 351.

TOWNSEND.
'**97**. Der Einfluss des Zellkerns auf die Bildung der Zellhaut. Jahrb. f. wiss. Bot., vol. 30, p. 484.

TROW.
:**01**. Biology and Cytology of *Pythium ultimum* n. sp. Annals of Bot., vol. 15, p. 269.

TROW.
:**04**. On Fertilization in the Saprolegnieæ. Annals of Bot., vol. 18, p. 541.

WAGER.
'**96**. On the Structure and Reproduction of *Cystopus candidus* Lev. Annals of Bot., vol. 10, p. 295.

WAGER.
'**99**. The Sexuality of Fungi. Annals of Bot., vol. 8, p. 575.

WAGER.
:**00**. On the Fertilization of *Peronospora parasitica.* Annals of Bot.. vol. 14, p. 263.

WEBBER.
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WEBBER.
:**01**. Spermatogenesis and Fecundation of Zamia. Bull. 2, Bureau Plant Ind., U. S. Dept. of Agric.

WILLIAMS.
:**04b**. Studies in the Dictyotaceæ. II. The Cytology of the Gametophyte Generation. Annals of Bot., vol. 18, p. 183.

WILSON.
:**00**. The Cell in Development and Inheritance. New York, 1900.

WOLFE.
:**04**. Cytological Studies on Nemalion. Annals of Bot., vol. 18, p. 607.

WOYCICKI.
'**99**. On Fertilization in the Coniferæ. (Russian.) Review, Bot. Zeit., vol. 58, p. 39, 1900.

CORRESPONDENCE.

Editor of the American Naturalist.

Sir: — Several articles have appeared in the *American Naturalist* of late on the common names of animals, and one of them introduces the question of their etymology. "There is in the human mind," as Max Müller sagely observes, "a craving after etymology, a wish to find out why such a thing should be called by such a name"; and this applies emphatically in the case of popular names in natural history.

Perhaps the most striking feature in the historical development of plant and animal vocabularies is the extent to which words have become metamorphosed, mutilated, deformed, or corrupted at the hands of the people, not only in English, but in all languages. One cannot but be impressed with the many curious travesties of the names of plants, insects, crustaceans, fishes, and higher animals which constitute a sort of verbal pathology, or "folk-etymology." There has been published recently a little essay on popular etymologies, which devotes considerable attention to instances of the latter description, and is sufficiently accurate to recommend itself to naturalists. We refer to *The Folk and their Word-Lore*, by A. Smythe Palmer (London, 1904), this being a companion work to the same author's *Folk-Etymology*.

Everyone is familiar with such typical examples of folk-etymology as "sparrow-grass," "cowcumber," and "shoe-mach," which are the popular recasting of familiar plant-names; but the majority of persons are probably unaware of the close verbal affinities existing between such words as lobster and locust, beaver and viper, crocodile and cockatrice, alligator and lizard, eagle-wood and alœ, and numerous other co-derivatives whose communal origin is more or less masked. When we read in old works, for instance, that "long oysters are a sort of crayfish," we do not immediately perceive that the latter word is only a modern modification of the older *crevish* (also written *crevis* and *crevice*), which in turn is derived from the same form that has yielded the French *écrevisse*, old-high German *Chrebiz*, and modern German *Krebs*; nor does the word "long oyster" or "longoister" resolve itself at first sight into an anglicized

form of the French *langouste*, or Spanish *langosta*, which lead us back to the Latin *locusta*. The example shows, however, how it is possible for folk-etymology to transform crayfish, which are indeed a variety of shell-fish, and may properly be described as long, into a "long oyster." So too "penny-winkle" for the shell-fish commonly called periwinkle, is a partial reversion to its original form *pinewincla*.

Many extraordinary verbal complications are brought about through the tendency to assimilate words of a foreign or unfamiliar aspect into something of like sound that shall be more intelligible. Amongst the innumerable corruptions of plant-names to which this process gives rise, may be mentioned "bloody Mars," a kind of wheat, for *blé de Mars*; "Christian anthems" for chrysanthemums; the various forms of *Polly Andrews*, *Polly Ann*, or *polander* for polyanthus; "rosy-dandrums" for rhododendrons; and the correlative "high-belia" and "low-belia" as offshoots from lobelia. Amusing illustrations of the same tendency are furnished by the soubriquets under which famous race-horses are known to grooms and jockeys. Thus, Chemisette was nicknamed *Jimmy's hat*; Othello and Desdemona were familiarized into "Old Fellow" and "Thursday Morning"; and the Irish horse Usquebaugh became to the farrier *Huskeyball*.

Professor B. K. Emerson, in relating the following anecdote, offers some instructive comments on the tendency toward assimilation, or as he calls it, "the principle of attraction in language whereby words without meaning to their users tend to be modified into forms which at least appear intelligible." Writes the genial professor[1]: "Many years ago I visited the British flagship *Bellerophon* in the harbor of Bermuda, and was told that when the ship was first named, the sailors wrestled with the sonorous but unmeaning name, and quickly transformed it into 'Billy-ruffian'; and it became at once intelligible, and belligerent, and satisfying. There arose, however, a contest in the forecastle as to whether 'Billy-ruffian' or 'Bully-ruffian' was the correct thing, — certain rude fellows of the baser sort wishing to have the word pugnacious in both its proximal and distal extremities."

The significance of this and of similar incidents that are common to everyday experience consists in their being typical of a distinct

[1] Geological Myths: Vice-Presidential Address. *Proc. Amer. Assoc. Adv. Sci.*, 1897, pp. 101–126.

process. Words are first attracted into a form which has a meaning, and in its turn this meaning requires a justification; and this the meaning itself quickly suggests. An understanding of this process has not only solved many philological problems, but finds an application in natural science. Emerson, for instance, in the address referred to, is guided by it to a rational interpretation of famous geological myths; and in the hands of Fouqué, the site of at least one volcanic eruption known to have taken place within historical times has been identified solely by linguistic clues of this nature.

C. R. Eastman.

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IN THEIR WIDEST SENSE

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AFFINITIES OF THE GENUS EQUISETUM.

DOUGLAS HOUGHTON CAMPBELL.

The genus Equisetum, as the survivor of an ancient race, which has otherwise completely disappeared, is of peculiar interest to the botanist. It is not strange that numerous attempts have been made to trace its history, and to determine its relationships to the other pteridophytes, recent and fossil.

The existing species of Equisetum, about twenty-five in number, are distributed over nearly the whole world — Australia alone, among the larger bodies of land, has no species in its flora. Some species, *e. g.*, *Equisetum arvense*, have a very wide range, while others, like *Equisetum giganteum*, are confined to a smaller area. The genus is sometimes subdivided, but the differences are of minor importance, and more commonly all the species are relegated to the single genus Equisetum.

There is a general agreement in the anatomical structure, perhaps the most marked difference being the variation in the relation of the endodermis to the vascular bundles. Thus, in certain species, like *Equisetum telmateia*, the ring of vascular bundles in the internodes is surrounded by a common outer endodermis, while in others, *e. g.*, *Equisetum hiemale*, each strand has its own sheath; while in a third type, represented

by *Equisetum silvaticum*, there is an inner as well as an outer endodermis, common to the whole circle of bundles. Other differences are the presence or absence of branches at the nodes, and the development in certain species, like *Equisetum arvense*, of special sterile and fertile shoots.

FOSSIL EQUISETALES.

The earliest fossils belonging to the Equisetales belong to the genus Archæocalamites, which in many respects was very similar, as regards both its anatomy and fructification, to the genus Equisetum. Fossils of undoubted equisetinean affinities abound in the later Palæozoic formations, being especially abundant in the coal measures. Of these, the genus Calamites was especially conspicuous. These were much more highly organized than the living Equiseta, which more nearly resemble the more ancient Archæocalamites. Fossils closely allied to the genus Equisetum occur frequently, however, in later formations, being abundant in the earlier secondary rocks.

Undoubtedly related to the Equisetales was the characteristic Palæozoic group of Sphenophyllales, but there is a good deal of diversity of opinion as to the possible connection of the Sphenophyllales with other groups of pteridophytes besides the Equisetales.

The genus Equisetum has been the subject of repeated investigation, and we are now well informed concerning pretty much all its structural details and developmental history. The conclusions drawn from a study of these data by different observers, however, are by no means all in accord. This difference is especially marked in the attempts to decide the affinities of the Equisetales with the other pteridophytes. It is mainly for the purpose of examining and comparing these divergent views that the present paper has been prepared.

Briefly stated, the following are the different views held as to the relationships of the Equisetales: —

1. They are allied to the lycopods.
2. They are allied to the ferns.
3. They are allied to neither of the other existing classes of pteridophytes, but have had an independent origin.

The first view has been strongly advocated by Scott[1] in England, who bases his conclusions upon a study of the fossil forms. In America, Jeffrey[2] has brought forward arguments in favor of the same view, from a study of both the gametophyte and sporophyte. He goes so far, indeed, as to propose a special division of the pteridophytes into the Lycopsida, and Pteropsida, the former including both Equisetales and lycopods, the latter the ferns.

As he has presented his arguments in very clear form, it may be well to consider them somewhat in detail, to see how they will stand the test of closer examination.

From a study of the gametophyte of Equisetum,[3] Jeffrey concludes that it most nearly resembles the gametophytes of such species of Lycopodium as *Lycopodium cernuum* or *Lycopodium inundatum*. "There are in both cases, the upright fleshy axis, and the same characteristically numerous lateral lobes. The archegonia of Equisetum and Lycopodium are, moreover, alike, in that in both genera they are uniformly without the basal cell, which is found without exception in the archegonia of all the isosporous Filicales" (*loc. cit.*, p. 186). He finds also that the neck canal cell is divided vertically as in *Lycopodium phlegmaria*, instead of transversely as is the case in the ferns.

Finally, in the embryo of *Equisetum hiemale* and *Equisetum limosum*, Jeffrey thinks that all the organs of the young sporophyte, including the primary root, develop from the upper or epibasal half of the embryo, in this respect also, showing a resemblance to the Lycopodiales.

The points in which the adult sporophytes of Equisetum and Lycopodium agree, are the highly developed axis, and small leaves; the development of a strobilus, and the so-called "cladosiphonic" vascular cylinder, or stele. It is on the basis of these resemblances that Jeffrey proposes the establishment of his micro-

[1] *Studies in Fossil Botany* — as well as many special papers.

[2] 1. The development, structure and affinities of the genus Equisetum. *Mem. Boston Soc. Nat. Hist.*, 1899: 2. Structure and development of the stem in the Pteridophyta and Gymnosperms. *Phil. Trans. Royal Soc.*, series B, vol. 195, 1902.

[3] Jeffrey, 1, p. 186.

phyllous and cladosiphonic Lycopsida, opposed to the megaphyllous, phyllosiphonic Pteropsida.

In his comparison of the gametophyte of Equisetum with that of Lycopodium, Jeffrey has overlooked a radical difference, to which Gœbel [1] has called attention, and which has been noted by other investigators. In the former genus, the gametophyte is dorsiventral, as it is in the ferns, and the archegonia originate

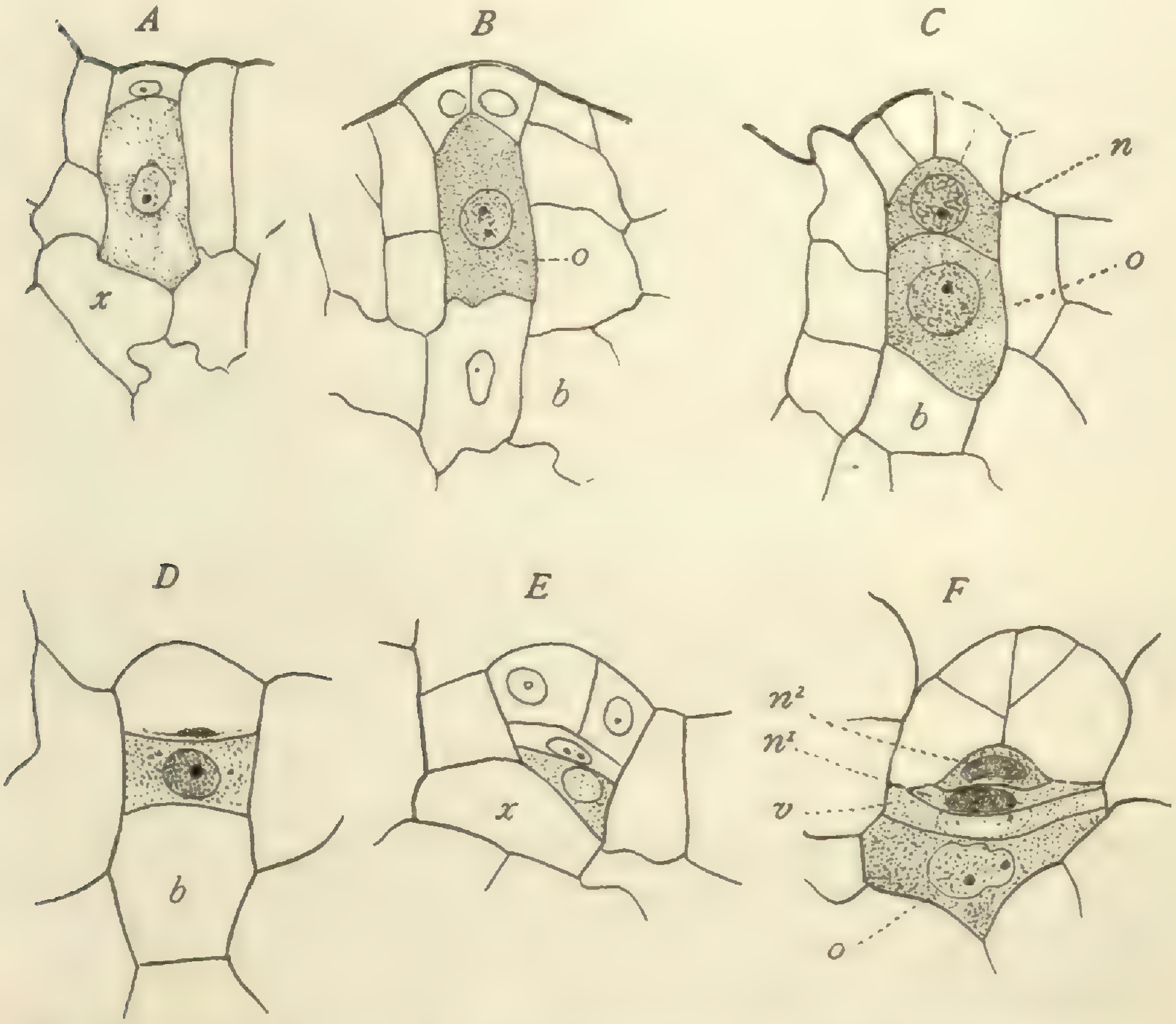

FIG. 1.—*A–C*, young archegonia of *Marattia douglasii*; *D–F*, young archegonia of *Equisetum telmateia*; *b*, basal cell; *x*, basal cell cut off before the isolation of the mother cell of the archegonium.

upon the ventral or shaded surface, the more or less conspicuously upright position being dependent upon light. The position of the archegonia upon the upper side of the prothallium is a secondary condition.

In Lycopodium the prothallium is radially constructed, the lobes being arranged equally about the upper part. The growth

[1] *Organographie der Pflanzen*. Zweiter Theil, Heft II, p. 409.

is marginal, and the meristem completely surrounds the upper part of the thallus, there being no proper apical growth as in Equisetum.

The gametophyte of Equisetum can much more properly be compared with that of the lower ferns like Osmunda or Marattia,

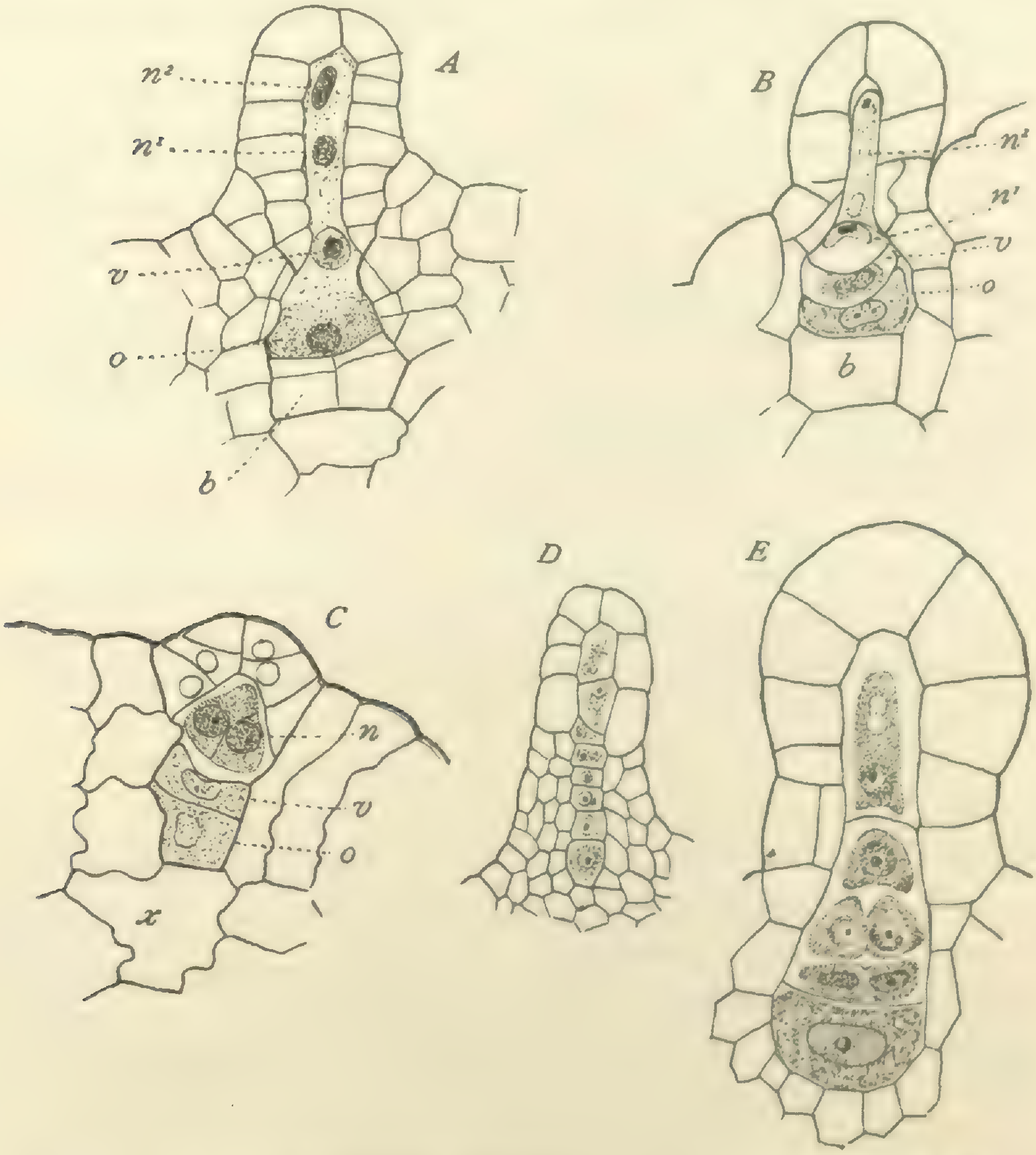

FIG. 2.—*A*, archegonium of *Botrychium virginianum*; *B*. *Equisetum telmateia*; *C*, *Marattia douglasii*, showing longitudinal division of the neck canal cell; *D*, *Lycopodium clavatum*; *E*, *Lycopodium phlegmaria*; *b*, basal cell; *o*, egg cell; *v*, ventral canal cell; *n*, *n'*, neck canal cells. (*D*, after Bruchmann; *E*, after Treub.)

and in the former genus especially there are sometimes developed lobes not essentially different from those found in the gametophyte of Equisetum.

As to the presence or absence of the basal cell of the arche-

gonium, this is probably not a point of fundamental importance. The writer has taken the trouble to examine this point somewhat carefully in *Equisetum telmateia*, *Marattia douglasii*, and *Osmunda cinnamomea*. In the former, an unmistakable basal cell was found in several instances (Fig. 1, *D*), although there is no question that ordinarily it is absent. Jeffrey states that in the species examined by him, it is universally wanting. In Marattia it was generally present, but much less conspicuous than in most ferns. Not infrequently, however, it was entirely wanting, as according to Jonkman (*Bot. Zeitung*, 1878), it is in the species of Marattia examined by him. Farmer says that in Angiopteris it is also absent.[1] In *Osmunda cinnamomea*, while ordinarily present, it may be wanting.

It is thus evident that too much stress cannot be laid upon the presence or absence of the basal cell. It is probably no more important than the pedicel in the archegonium of the Marchantiaceæ. *Marchantia polymorpha*, for instance, regularly develops such a pedicel cell, while in Targionia and Fimbriaria, it is regularly absent, and the archegonium is closely sessile.

An interesting condition was noted in several cases in Equisetum (Fig. 1, *E*) where a basal cell was developed before the final cutting off of the mother cell of the archegonium. An exactly similar case was found in Marattia (Fig. 1, *A*).

Jeffrey has described a peculiarity in the archegonium of Equisetum which he thinks points to a relationship with Lycopodium as in one species, *Lycopodium phlegmaria* (Fig 2, *E*), a similar condition has been found. This is the longitudinal division of the neck canal cell. To judge from my own preparations of *Equisetum telmateia*, this rarely occurs in that species, where the division wall is normally transverse, as it is in the ferns (Fig. 1, *F*), and most other Archegoniates. A similar longitudinal division has been observed in species of Isoetes.[2] In one instance a similar longitudinal division was found in Marattia (Fig. 2, *C*).

To summarize: it seems to the writer that in all respects

[1] *Annals of Botany*, vol. 6, 1892.

[2] Arnoldi, *Bot. Zeit.*, 1896; Lyon, *Bot. Gazette*, 1904.

there is decidedly more resemblance between the gametophyte of Equisetum and that of the lower ferns than there is between it and any species of Lycopodium.

The Embryo.

According to Sadebeck,[1] who has made a special study of the embryo of Equisetum, the primary or basal wall of the embryo, which is transverse, divides the embryo into an upper or epibasal cell, and a lower or hypobasal one. From the epibasal cell is derived the apex of the shoot; from the hypobasal one the foot and the primary root. My own studies upon *Equisetum telmateia*, although not complete, confirm Sadebeck's statement. Jeffrey[2] thinks it doubtful whether the root in *Equisetum hiemale* and *Equisetum limosum* originates from the hypobasal region of the embryo, but to judge from his figures 7, 8, it is by no means certain that his interpretation is correct. While comparing the embryo of Equisetum with that of Lycopodium, in which all of the organs of the embryo arise from the epibasal half, he fully recognizes the fact of the presence of the suspensor in the lycopods, and its absence in Equisetum. Even if his assumption of the epibasal origin of the root were correct, it could more aptly be compared with the embryo of Botrychium, where he has shown[3] that both root and shoot are of epibasal origin, and moreover, the cotyledon develops secondarily from the shoot as the first foliar sheath does in Equisetum.

The Mature Sporophyte.

The sporophyte of Equisetum, as is well known, differs widely in its general structure from either the ferns or lycopods. The structural type as it exists in the living horsetails is evidently a very ancient one, and the oldest fossils belonging to the Equisetales are not essentially different in their structure from the living species.

[1] *Bot. Zeit.*, 1877.
[2] *Loc. cit.*, p. 169.
[3] The Gametophyte of Botrychium. *Proc. Canad. Institute*, vol. 5, 1898.

The hollow jointed stem, the remarkably regular apical growth of both shoot and root, and the structure and arrangement of the vascular bundles are very different from the lycopods with which it has been attempted to connect the Equisetales. It is true that both the latter class and the lycopods are characterized by relatively small leaves, but their structure and relation to the shoot are very different in the two classes.

It may be questioned whether the excessive reduction of the leaves found in most species of Equisetum is not a secondary condition. The oldest known type, Archæocalamites, while agreeing closely in its general structure with Equisetum, differed in the very much better developed leaves, which not only were much larger than those of Equisetum, but were repeatedly branched in a dichotomous manner, more suggestive of the leaves of certain ferns than of any forms among the lycopods. Their relation to the shoot, however, was precisely that of the existing forms. The peculiar extinct order, the Sphenophyllales, which are admittedly of equisetaceous affinities, also possessed dichotomously divided leaves, or wedge-shaped leaves with dichotomous venation.

The fact that both Equisetales and lycopods have the sporangial structures arranged in a strobilus or cone, can hardly be taken as a necessary indication of relationship. The structure of the cones in the two classes is very different, the sporangiophores of Equisetum being hardly comparable to the true sporophylls of Lycopodium. Moreover, true strobili are known in the fern series, as shown by the cycads, whose relationship with the ferns is now almost universally admitted.

While the structure of the sporangia and of the spores is extremely characteristic in Equisetum, the development of the sporangium is much more like that of the eusporangiate ferns than like that of any of the Lycopodineæ.

Jeffrey lays much stress upon the arrangement of the vascular bundles in Equisetum, which he thinks can be compared better to those of the Lycopodiales than to those of the ferns. Van Tieghem,[1] on the other hand, refers Equisetum to his

[1] *Traité de Botanique.*

"astelic" type, to which Ophioglossum also belongs. Whether or not Equisetum is astelic in Van Tieghem's sense, there is a very important respect in which it differs from the other pteridophytes that have been critically studied, namely, the origin of the vascular bundles from the cortical region, and not from the primary central cylinder. A longitudinal section of the shoot shows an early differentiation into a central cylinder and cortex, but it is from the latter and not from the former that the vascular strands originate, the central cylinder developing only the pith.

Jeffrey in his study of the development of the vascular system in the young sporophyte does not state whether the relation of the vascular strands to the primary central cylinder is the same as in the adult sporophyte, but there is no reason why it should be different, as otherwise the arrangement of the bundles is the same.

He states that the arrangement of the bundles in the primary shoot is the same as in the later ones, except that he finds at the base of the shoot below the first leaf sheath, a closed ring of vascular tissues, such as occurs at the nodes, and considers this as a remnant of a primitive cylindrical stele or vascular cylinder; but it is not quite clear why this does not simply represent the first node where we should expect to find essentially the same arrangement of the tissues as in the later nodes.

As in the later shoots, there extend between the nodes separate vascular strands corresponding in number to the teeth of the leaf sheaths,— three as a rule in the primary shoot. These fork at the nodes, and each branch joins one from the neighboring bundle, so that the vascular strands alternate in succeeding internodes as they do in the later formed shoots.

In Archæocalamites, the earliest known type, the bundles are continuous from one internode to another, but in the Calamites of the Carboniferous, the same arrangement is found as in Equisetum.

Jeffrey considers the spaces between the internodal strands as gaps in an originally continuous cylinder, comparable to the large foliar gaps found in the cylindrical stele of the ferns, or the ramular gaps, occurring where branches are given off, in the

lycopods. From a study of the fossil Equisetales, especially Archæocalamites, he concludes that these gaps are to be considered as ramular gaps, although he admits that in Equisetum they occur opposite the leaves. He proposes the term "cladosiphonic" to designate a cylindrical stele, with ramular gaps, such as he assumes for the Equisetales and Lycopodiales.

Admitting that the vascular system of Equisetum can be referred to a siphonostelic type, it is hard to see how we can reconcile Jeffrey's idea of cladosiphony with the facts. So far as we can see there is absolutely no difference in the arrangement of the bundles of the internodes and their intervening spaces in shoots which develop branches, and those which are without them. In all cases, the number of internodal strands — and, of course, that of the gaps between them — corresponds to the number of leaf traces developed from the foliar sheath. The gaps are equally present in the primary unbranched shoot, and in the densely branched sterile shoots of *Equisetum arvense* or *Equisetum telmateia*. It certainly seems hardly reasonable to suppose that an ideal branch — so to speak — could cause the development of a ramular gap, when no actual branch is present.

Jeffrey lays stress upon the fact that in Archæocalamites, the branches are really opposite the spaces between the internodal vascular strands; but it appears [1] that Archæocalamites was often very sparingly branched, but this does not seem to bear any relation to the presence of the alleged ramular gaps, which are perfectly developed whether branches are present or not.

We see no reason why we should try to reduce the vascular system in the Equisetales to either of the types found in the other phyla of pteridophytes. The peculiar character of the stem, with its hollow jointed structure, would naturally involve quite a different arrangement of the tissues. Moreover, as has already been indicated, the origin of the vascular strands is entirely different from that of the typically axial vascular cylinders of the other classes. There is no valid reason why the separate strands in Equisetum may not have existed from the

[1] Scott, *loc. cit.*, p. 65: Potonie, *Lehrbuch der Pflanzenpalæontologie, 1899.*

first. The oldest fossils show the same type, and in the embryo, before any trace of the vascular bundles can be seen, there is developed the three-leaved primary foliar sheath, and corresponding to the three teeth of the foliar sheath, are developed simultaneously the three vascular strands of the first internode.

The Sphenophyllales.

The Sphenophyllales are exclusively fossil forms which show evident affinities with the Equisetales, from which they differ especially in the arrangement of the tissues of the stem. Instead of the large central cavity found in the stem of Equisetum, Sphenophyllum has an axial solid vascular cylinder more like that of the modern lycopodiaceous forms than like any other existing pteridophytes.

Scott[1] considers that the Sphenophyllales are to some extent intermediate between Equisetales and Lycopodiales, basing his opinion mainly upon the anatomical characters, especially those of the stem. The peculiar fossil Cheirostrobus[2] he especially considers a synthetic type, having the sporangia of the Equisetum type, but the vascular system of a lycopod.

Potonie[3] holds that the Sphenophyllales are an early offshoot of the equisetaceous series, perhaps directly connected with Archæocalamites. The characteristic triarch or hexarch bundle of the stem suggests a three-sided apical cell like that of Equisetum, but in the Psilotaceæ, which are commonly associated with the Lycopodiales, there is a somewhat similar type of stele, and these forms also have a single tetrahedral initial cell in the shoot.

One objection to considering the Sphenophyllales a synthetic type is that all the existing types of pteridophytes were clearly differentiated in formations earlier than any in which remains of the Sphenophyllales certainly occur.

[1] *Studies in Fossil Botany*, 1900.
[2] *loc. cit.* pp. 106–114.
[3] *loc. cit.*, p. 180.

The peculiar, jointed, hollow stem, with the characteristic arrangement of the bundles, except for their alternation in succeeding internodes, is as marked in the earliest Equisetales as it is in the existing genus, and cannot readily be derived from either the type of the ferns or lycopods, both of which are clearly recognizable in the formations where they first occur. So far as we can judge from the geological record, the central solid stele of Sphenophyllum is a more recent development than the separated vascular strands of the typical Equisetales, as exemplified by Archæocalamites.

CONCLUSIONS.

As we have endeavored to show, the gametophyte of Equisetum resembles that of the eusporangiate ferns rather than Lycopodium, both in its dorsiventral character, and method of growth, and especially in the large multiciliate spermatozoids. We believe that these resemblances indicate a real, although extremely remote, relationship with the lower ferns.

The early divisions of the embryo are not unlike those in the fern embryo, but the early preponderance of the shoot, and the subordination of the leaves, very soon produce an extremely different type of sporophyte, and it is highly probable that the peculiarities of the sporophyte were established at a very remote period, and are not modifications of another type. The dichotomously divided leaves of the older Equisetales and Sphenophyllales are somewhat reminiscent of those of some ferns, although it is not at all likely that there is any direct genetic relationship between these.

The most probable conclusion to be reached, in view of the evidence at hand, would seem to be that the two series, the ferns and Equisetaceæ, are descended from a common stock, in which the gametophyte was not unlike that of the existing species of Equisetum and the lower eusporangiate ferns. It must be assumed, however, that the peculiarities of the sporophytes became established at so remote a period that one cannot say that either was derived from the other — *i. e.*, from the same ancestral stock represented by the gametophyte as it now exists

in the two classes, there arose quite independently two types of sporophyte: one distinguished by a preponderant development of the shoot, the other marked by the great development of the leaf structures.

Neither of these classes is at all related to the Lycopods, which show strong evidences of being derived independently from a very different type of gametophyte.

STANFORD UNIVERSITY.

MOVEMENTS OF DIATOMS AND OTHER MICROSCOPIC PLANTS.

DANIEL D. JACKSON.

FEW subjects in the domain of cryptogamic botany have given rise to more speculation and conflicting theories than have the studies into the cause of the apparently voluntary movements of diatoms. From time to time for the past twelve years the author has been confronted with this seemingly fruitless subject, and only recently, almost by accident, has the problem been solved.

It was early shown by examination in closed cells that the phenomenon was not due to external currents set up in the surrounding liquid, but that the power of motion came from the organism itself. Largely on account of these movements, which appeared to be spontaneous and voluntary, the diatoms were originally classed in the animal kingdom.

The first theory which naturally presented itself was that they move as do the Infusoria by means of vibrating hair-like cilia or flagella. Later certain authors claimed to have seen protoplasmic processes similar to those of the rhizopods protruding from the small openings in the frustule of the organism. Then came the theory of Onderdonk [1] which described the progression as due to a thin fluid mass in rhythmical motion covering the surface of the diatom.

Nägeli suggested that the motion is due to endosmotic and exosmotic currents, and H. L. Smith [2] after much study of the subject came to the conclusion "that the motion of the Naviculæ is due to injection and expulsion of water, and that these currents are caused by different tensions of the internal membranous sac in the two halves of the frustules."

[1] The Movements of Diatoms. *The Microscope*, August, 1890.

[2] A Contribution to the Life History of the Diatomaceæ. *Proc. Amer. Soc. Microscopists*, 1888.

In order to prove this theory, Professor Smith showed by means of suspended indigo that when the diatom moves forward the particles of indigo gather around the central nodule of the valve and form a small mass which turns on itself just as if it was impelled by a jet of water proceeding from the valve at this point. Each of these little turbulent spheres after having acquired a certain size, falls apart and the particles which compose it are driven along the valves from front to back and accumulate behind the extremity of the frustule which, according to its progression, would be considered the rear. The particles move as if they were subjected to a current going from front to back, and reverse when the motion is reversed. That these currents exist there can be no doubt, but that the motive power is not due to the expulsion of water will shortly be demonstrated.

The first intimation of the true nature of this motion was suggested by the action of a lithia tablet in a glass of water. The bubbles of carbonic-acid gas given off set up the exact motions in the tablet that have been so often described for the movements of diatoms: "A sudden advance in a straight line, a little hesitation, then other rectilinear movements, and, after a short pause, a return upon nearly the same path by similar movements."

Repeated experiments with compressed pellets evolving gas have shown that this is the usual motion produced by the evolution of gas bubbles, and when pellets were made of the same shape as Navicula the movements of these diatoms were perfectly duplicated. Boat-shaped pieces of aluminum two millimeters thick were then made and on them were cut longitudinal grooves to resemble those of the diatom. When placed in strong caustic soda solution the movements of the metal produced by the evolution of hydrogen gas again duplicated those of the diatom in a remarkable manner. The metal having the grooves had a greater power of motion than that without the grooves.

If we consider that the diatom contains chlorophyll bands which when exposed to a strong light rapidly evolve oxygen, and if we take into account the fact that the motion does not take place unless the light is fairly strong, we have then a conception of the true nature of the movements of these organisms.

Streams of oxygen may be readily seen evolving from all parts of many of the larger aquatic plants when submerged in water and exposed to strong light, but in the diatom while the gas produced is large in amount compared with the size of the organism, the actual amount evolved is so small that it is taken into solution almost immediately. That such evolution takes place, however, is shown by Professor Smith's experiments with indigo. If now we examine the artificial diatom made of aluminum and placed in strong caustic solution we find that the bubbles from all sides come together and rise in a line corresponding to the median line or raphe of the organism, and that if indigo is placed in the liquid it collects and rotates near the central nodule just as described by Professor Smith to prove his theory of the presence of water currents.

It is therefore evident that the motion of diatoms is caused by the impelling force of the bubbles of oxygen evolved, and that the direction of the movement is due to the relatively larger amount of oxygen set free first from the forward and then from the rear half of the organism. This accounts for the hesitancy and irregular movements as well as the motion forward and backward over the same course.

The evolving gas seems to act at times as a propeller to push the organism forward and at other times to exert a pulling action to raise the growth on end. The various movements described are the resultants of varying proportions of both of these active forces.

The fact that a longitudinal groove on the under side of the artificial diatom causes it to become more active, due to the expulsion of the gas along the line of the groove, explains the greater activity of the Raphideæ.

The most interesting and peculiar movements among diatoms are those of *Bacillaria paradoxa* whose frustules slide over each other in a longitudinal direction until they are all but detached and then stop, reverse their motion and slide back again in the opposite direction until they are again almost separated. When the diatoms are active, these alternating movements take place with very considerable regularity. It is probable that the individuals in a group of Bacillaria are joined together much more

loosely than other laterally attached genera and that when a forward movement takes place in the outer individual it is arrested by capillarity just before the diatom is completely detached.

It can now be readily seen that the strange movements of the other microscopic plants may be explained as also due to the evolution of oxygen gas. While the movements of desmids are not as strongly marked as those of diatoms, many of them, notably Penium and Closterium, have often been described as having a power of independent motion, and Stahl[1] found that this motion is greatly affected by light.

The best account of the movements of desmids has been given by Klebs.[2] This author speaks of four kinds of movements in desmids, *viz.*: —

(1) A forward motion on the surface, one end of each cell touching the bottom, while the other end is more or less elevated and oscillates backwards and forwards.

(2) An elevation in a vertical direction from the substratum, the free end making wide circular movements.

(3) A similar motion, followed by an alternate sinking of the free end and elevation of the other end.

(4) An oblique elevation, so that both ends touch the bottom — lateral movements in this position; then an elevation and circular motion of one end, and a sinking again to an oblique or horizontal position.

This observer considered these movements to be due to an exudation of mucilage, and the first two to the formation, during the action, of a filament of mucilage by which the desmid is temporarily attached to the bottom and which gradually lengthens.

These four kinds of movements are very easily explained by the theory of the evolution of gas, and by regulating the conditions they can be exactly reproduced in the artificial desmids made of aluminum. In this case strips of thin aluminum foil should be used. When the gas production is very strong at one

[1] *Verhandl. phys. med. Gesellsch. Würzburg*, 1880, p. 24.
[2] *Biol. Centralblatt*, 1885, p. 353.

end, the desmid will be raised to a vertical position and will take up oscillating or circular movements.

If we now pass to a consideration of like movements in the Cyanophyceæ, the same explanation holds true for Oscillaria which often takes up a waving or circular motion when attached at one end. This movement is well described by Griffith and Henfrey[1] as follows: "The ends of the filaments emerge from their sheaths, the young extremities being apparently devoid of their coat; their ends wave backward and forward, somewhat as the forepart of the bodies of certain caterpillars are waved when they stand on their prolegs with the head reared up." The authors attribute this motion to "irregular contraction of the different parts of the protoplasm."

The free-swimming species of Nostoc all have a spontaneous power of active motion in water, and in all of the filiform orders of the Cyanophyceæ, detached portions of the filament known as hormogones also have the power of spontaneous motion. All of these movements can be exactly duplicated with lithia tablets in water or with aluminum of the proper weight and shape immersed in strong caustic solution, and are also undoubtedly caused by the strong evolution of oxygen gas due to the activity of the chlorophyl present in the organisms.

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[1] *Micrographic Dictionary*, p. 561.

SYNOPSES OF NORTH AMERICAN INVERTEBRATES.

XX. Families and Genera of Araneida.

NATHAN BANKS.

The body of a spider is very distinctly divided into two parts: the anterior, or cephalothorax, or carapace, and the posterior, or abdomen. The cephalothorax is supposed to be the equivalent of the head and thorax of insects. Near the middle of the cephalothorax is a dorsal or median groove; from this groove radiate furrows, called radial furrows. The region of the cephalothorax between the anterior pair of furrows is called the pars cephalica, or head; the part behind is known as pars thoracica. The eyes are situated upon the front part of the pars cephalica; the region they occupy is known as the eye-region, eye-area, or ocular area. The eyes are usually eight in number, sometimes six, more rarely two or none. They are arranged in transverse rows, often two, sometimes three or four. References to the eyes are in the form of abbreviations, S. E., meaning side eyes; A. E., anterior eyes; P. E., posterior eyes; M. E., middle eyes; P. M. E., posterior middle eyes; A. S. E.,

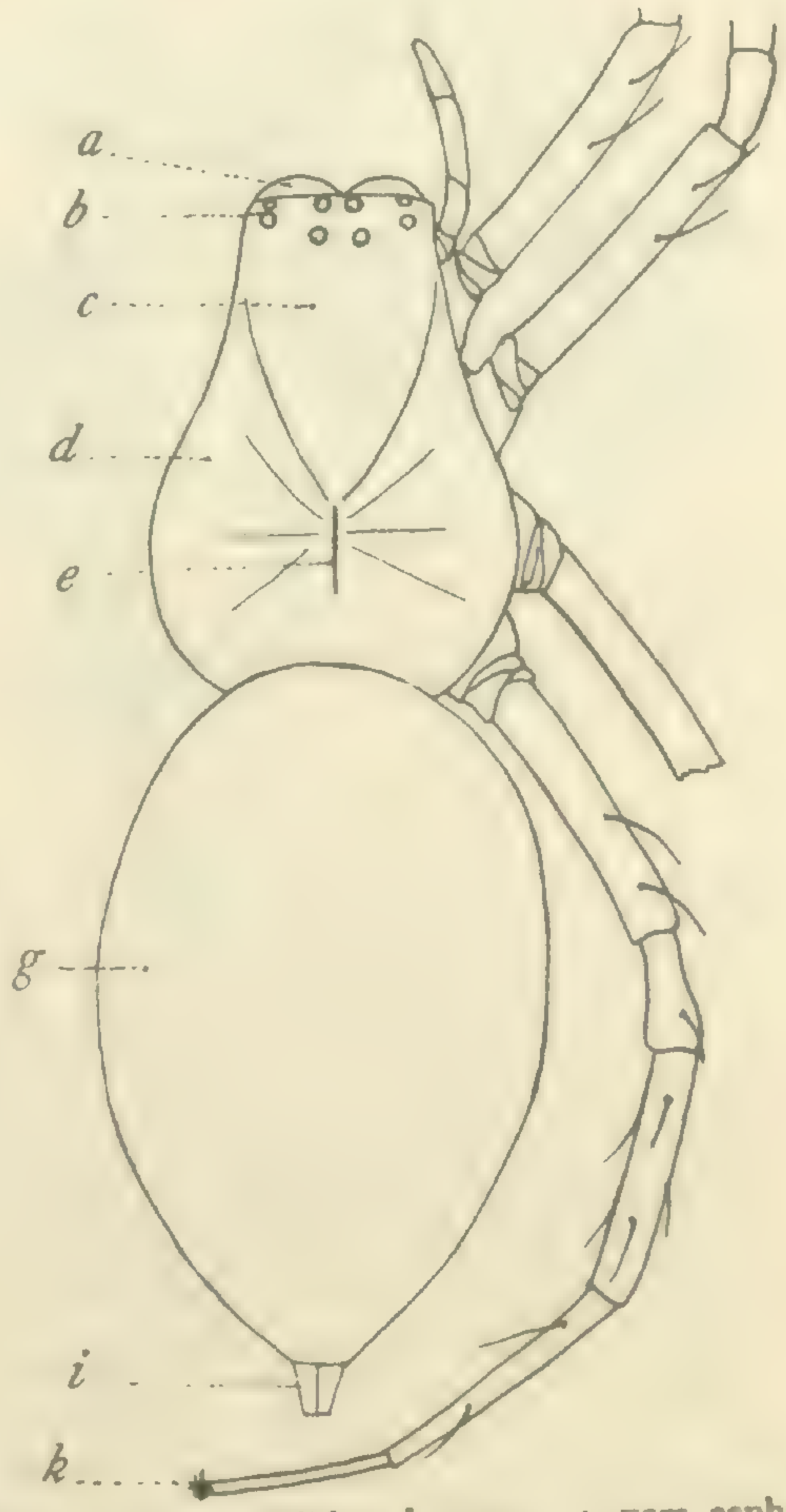

Fig. 1.—*a*, mandible; *b*, eyes; *c*, pars cephalica; *d*, cephalothorax; *e*, dorsal groove; *g*, abdomen; *i*, spinnerets; *k*, claws.

anterior side eyes, etc. Sometimes the most posterior eyes are called the dorsal eyes. An eye-row is either straight or curved. When the S. E. of a row are farther back than the M. E. of that row, the row is said to be recurved; when the S. E. are more forward, the row is procurved. Dark-colored eyes are considered to be diurnal in function, and pale eyes nocturnal. Many spiders have both kinds and the difference in appearance of the two is often very striking. The arrangement of the eyes is of the greatest importance in systematic araneology. The space between the anterior eye-row and the front or clypeal margin of the cephalothorax is called the clypeus, or fillet. Attached just below the clypeal margin are the mandibles, jaws, falces, or cheliceræ, as they are variously termed. Each is of two parts: the basal joint, or larger part, and the fang, or apical part. The fang fits down into a groove of the basal joint, which is often margined with a few small teeth. The poison glands open near the tip of the fang. The mandibles are usually vertical, sometimes uplifted, or porrect. Sometimes they are divergent, and in some cases the basal part is swollen above in front, and the mandible is then said to be geniculate. At the outer base of each basal joint there is, in some families, a small area separated from the rest of the surface; this is styled the boss, or lateral condyle.

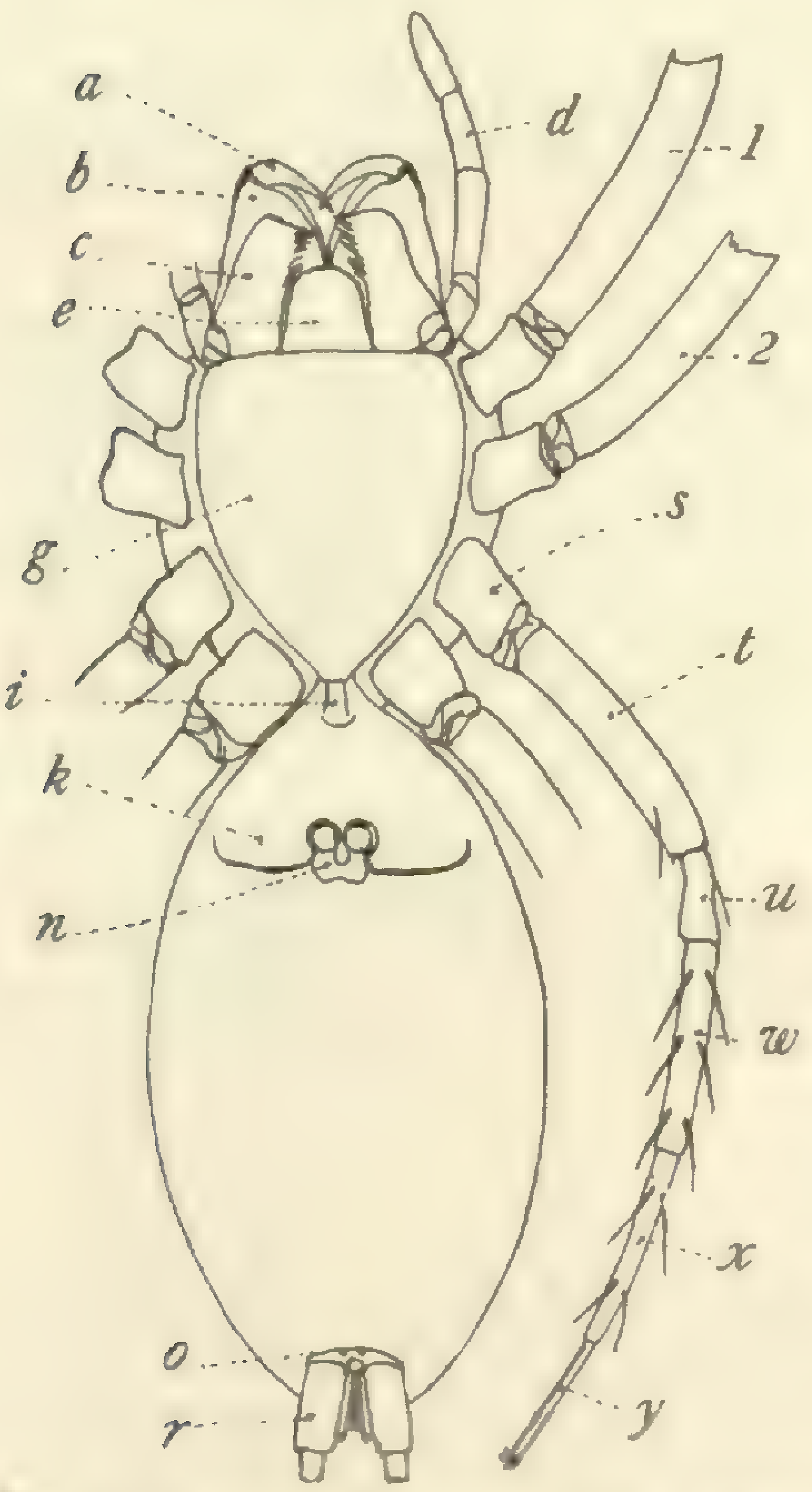

FIG. 2.—*a*, fang; *b*, mandible; *c*, maxilla; *d*, palpus; *e*, lip; *g*, sternum; *i*, pedicel; *k*, epigastric plate; *n*, epigynum; *o*, rima ventralis; *r*, spinnerets; *s*, coxa; *t*, femur; *u*, patella; *w*, tibia; *x*, metatarsus; *y*, tarsus; *1*, leg I; *2*, leg II.

The mouth-parts seen from below are a median piece, the lip or labium, and a piece on each side, the maxillæ, or endites. In some cases the maxillæ show an oblique furrow or impres-

sion. Each maxilla bears a jointed appendage, the palpus. In the female, the palpus is always simple, but in the male, when mature, the last joint is enlarged, concave within, and furnished with a number of more or less corneous and curved pieces, which serve as accessory sexual organs. The shape of these male palpi is of great value in the study of species. The sternum is the ventral plate of the cephalothorax; it is surrounded by the eight legs. In some species there are scars or impressions on the sternum. The legs are numbered from before backward as follows: I, II, III, IV. They are seven-jointed, each joint from the basal outward known as follows: coxa, trochanter, femur, patella, tibia, metatarsus or protarsus, and tarsus; in a few forms there is a small eighth joint, the onychium. At the tip of the tarsus, or onychium if present, are two claws, equal in size; below and between them, in some families is a third claw. Sometimes in place of the third claw there is a dense brush or fascicle of hair. The claws are often toothed or pectinate. In a few groups there are specialized branched hairs at the tip of the tarsus which may act as accessory claws. Sometimes there is a brush of hairs along the lower side of the tarsus or metatarsus; this is called a scopula. Sometimes there is a row of serrate bristles under tarsus IV; this is known as a comb.

FIG. 3.—Tarsi with two claws and brush, and with three claws.

The abdomen is joined to the cephalothorax by a slender pedicel. At or near the tip of the abdomen on the under or ventral side are the spinning organs, or spinnerets. They are of three pairs, the middle pair smaller and concealed by the other two. Sometimes one pair is very plainly of two joints. At the base of the lower pair there is sometimes a transverse surface provided with (Fig. 4) spinning tubes similar to those of the spinnerets; this is the cribellum. Comple-

FIG. 4.—Cribellum.

mentary to this in function is a row of stiff hairs or bristles on each posterior metatarsus, known as the calamistrum (Fig. 5). The spider possessing these accessory spinning organs can produce a peculiar curled silk by using the calamistrum to comb out the threads from the cribellum. In some cases there is a conical piece between the lower pair of the spinnerets, termed the colulus. In the tarantulas and allied spiders there is a small post-abdomen above the spinnerets. Near the base of the spinnerets is a pair of stigmata or tracheal spiracles; these are sometimes placed more anteriorly, and even as near the base as the tip of the abdomen. When so situated a transverse fold or furrow is formed, known as the ventral furrow, or rima ventralis. Near the base of the abdominal venter is a transverse slit on each side. These are the lung-slits or epigastric furrows, which open into the breathing organs called lung-books. In some spiders there are two pairs of these slits, or there may be a tracheal spiracle behind the first pair. The hardened cuticle over the lung-books forms the epigastric plates. Between the plates on the median line is the opening of the reproductive organs. The genital aperture of the female is termed the epigynum or vulva, and that of the male, small and inconspicuous, is the epiandrium. The epigynum is often of a very complicated nature, and is of much value in the study of species. In some cases there is a pointed piece projecting below the abdomen known as the finger of the epigynum. The furrow behind the epigynum is called the rima genitalis. In some forms there are corneous plates, shields, or scutæ on the abdomen, either above or below. Small circular spots are sometimes called sigillæ.

FIG. 5.— Calamistrum.

The legs and body are clothed with hairs, bristles, scales, or articulated spines. The arrangement of the latter upon the legs is often of great systematic value. If there are two rows of these under tibia I, each row of three spines, then tibia I is said to have spines 3–3. Sometimes these hairs or bristles form tufts, crests, or fringes. On the dorsum of the abdomen there is sometimes a leaf-like mark known as the folium. In some cases there are short, oblique marks in pairs on the dorsum;

these are called chevrons. The legs may have longitudinal marks — stripes; or transverse marks — bands.

Spiders at birth are often very different from their later stages, so that it is impracticable to identify them by tables prepared for adults. However, many spiders when one or two months from maturity are sufficiently similar to their parents to be placed in the proper genus. None but specialists should attempt the specific identification of immature spiders. At maturity the female has her epigynum exposed, and the male has the complicated structures of the palpi uncovered. Spiders without these developments should not be studied by the beginner. There are a few forms of uncertain generic position which have not been included in the tables. They are rare, doubtless more so than various new generic forms that have not yet been collected, though occurring in our country. The spider fauna of many portions of the South and West has been only slightly explored, while a closer examination of our southern borderland will reveal various genera now known to occur in Central America only. Nevertheless the more common spiders in any portion of our country will be found in the following tables

MYGALOMORPHA.

Two pairs of lung-slits on venter of abdomen: fangs of mandibles moving vertically, parallel to each other.

1. Legs very long and slender, femur I longer than body . . . Hypochilidæ.
   Legs short and heavy, femur I shorter than body . . . Theraphosidæ.

ARACHNOMORPHA.

But one pair of lung-slits on venter of abdomen: fangs of mandibles moving somewhat horizontally, toward each other.

1. Without eyes: small pale cave spider (Antrobia) . . . Linyphiidæ.
   With six or eight eyes . . . . 2.
2. With eight eyes . . . . 3.
   With but six eyes . . . . 31.
3. All eyes close together upon a small tubercle or eminence: large species, yellowish brown or brown in color . . . . . Filistatidæ.
   All eyes not situated upon a small median tubercle . . . 4.
4. Apex of abdomen surrounded by a circle of bent hairs: small species

with flat cephalothorax, maxillæ curved around lip, and the posterior, middle eyes elongate and curved; eyes not in two transverse rows . . . Urocteidæ.

No circle of bent hairs around tip of abdomen . . . . . 5.

5. With a cribellum and calamistrum in female . . . . . 29.

Without cribellum and calamistrum . . . . 6.

6. Eyes always in three or four transverse rows; eyes of next to last row extremely small, the middle eyes of first row (or the first row in Lyssomanes) are very much larger than other eyes; clypeus always vertical, never sloping; cephalothorax never very broad, legs rather short; jumping spiders . . . . Attidæ.

Eyes in two or three rows; when in three rows, then the middle of first row are not greatly larger than any others, and those of second row not greatly smaller than others . . . . 7.

7. Each tarsus with three claws: spinning webs; or else eyes are often in three rows . . . . 14.

Each tarsus with but two claws; never spinning webs; eyes rarely in three rows; S. E. rarely contiguous; never with but two spinnerets 8.

8. Posterior eye-row so much procurved as to represent two rows, the P. M. E. oval: maxillæ long and tapering; fang of mandibles very long: trochanters longer than usual, anterior coxæ much longer than others . . . Prodidomidæ.

Without such combination of characters . . . . . . 9.

9. P. M. E. large, closer to the small A. S. E. than the latter are to the A. M. E., which are also small; tarsi with scopula; cephalothorax not broad and flat, legs rather laterigrade . . . . . . Ctenidæ.

P. M. E. not as close to A. S. E. as latter are to A. M. E., or if so, then eyes nearly equal in size . . . . 10.

10. P. M. E. black; legs I and II laterigrade, that is, articulated so that the anterior surface is directed upward. Second pair of legs nearly always as long as the fourth, or longer, and about as large and long as leg I; spinnerets not prominent; cephalothorax usually broad and abdomen often depressed . . . . 11.

P. M. E. pale, only A. M. E. dark; legs I and II not laterigrade; leg II usually noticeably shorter or smaller than either leg IV or leg I; cephalothorax longer . . . . 13.

11. A. M. E. some distance from clypeal margin, tarsi often not scopulate: spiders of medium size . . . . Thomisidæ.

A. M. E. close to clypeal margin, cephalothorax flatter, tarsi heavily scopulate, mostly large spiders . . . . 12.

12. Tarsal claws pectinate, maxillæ not inclined over lip: very large spiders . . . Sparassidæ.

Tarsal claws smooth, maxillæ inclined over lip; spiders of moderate size . . . Zodariidæ.

13. Lower spinnerets distinctly separated, rather long and prominent;

maxillæ with an obliquely transverse furrow or groove, outer side often concave; abdomen often depressed . . . . . . Drassidæ.

Lower spinnerets contiguous; maxillæ usually without furrow, outer side convex . . . . Clubionidæ.

14. With but two spinnerets, which are very prominent, but not two-jointed, eyes in two rows, legs short and heavy; maxillæ inclined over lip Zodariidæ.

With six spinnerets . . . . 15.

15. Three eyes on each side in a group, the P. M. E. touching the P. S. E.; cephalothorax rounded and flat, the pars cephalica very small; legs long and without spines, maxillæ surrounding the lip . . Pholcidæ.

P. M. E. never touch P. S. E.; only two eyes in side group, pars cephalica occupying entire front of cephalothorax . . . . 16.

16. Eyes in two rows, more or less curved; no scopula; P. S. E. never much larger than eyes of front row; when P. M. E. are as far apart as A. S. E. (which is rare) then the legs are not spined . . . 17.

Eyes usually in three (or four) rows, when in two rows, then the P. S. E. are much larger than the eyes of front row, or the tarsi are scopulate, or the P. M. E. are farther apart than the A. S. E. (Hamataliva), and the legs spined . . . . 24.

17. Legs I and II long, with rows of two kinds of spines, one long, and the other in between are very short and curved . . . Mimetidæ.

No such spine arrangement on legs . . . . 18.

18. Males only: — mandibles concave from in front, and bowed outward in middle; tibia of male palpus with a process on outer side at base Dictynidæ.

Males and females: — former never with such mandibles, and tibia of palpus not often armed at base . . . . 19.

19. Upper spinnerets long and two-jointed; or else with the mandibles geniculate at base, and the A. M. E. only dark; no comb on hind tarsi; legs with spines; making flat irregular webs . . . . . 20.

Upper spinnerets not long and two-jointed, mandibles not prominently geniculate at base, other eyes besides A. M. E. are dark; S. E. often contiguous . . . . 21.

20. Males only: — A. M. E. scarcely diameter from clypeal margin, upper spinnerets not two-jointed . . . . Dictynidæ.

Males and females: — upper spinnerets two-jointed, or else the A. M. E. are some distance from clypeal margin . . . . . Agalenidæ.

21. A comb on hind tarsus; legs usually without spines; abdomen often globose; maxillæ inclined over lip; clypeus as high as eye-area Theridiidæ.

No such comb; maxillæ usually less inclined over lip; spines often present on legs . . . . 22.

22. Epigynum of female a simple slit; male palpus has a bulb on end of

tarsus terminating in a simple tube; legs rather short, body never high and broad; mandibles not large and porrect . . . Scytodidæ.

Male palpus has the palpal organ quite complicated, and the tarsus partly covers it; the epigynum is more than a slit, else the mandibles are large and porrect, or the abdomen very elongate . . . . 23.

23. At base of mandibles on outer side is a striate or roughened area; clypeus high, higher than height of eye-area; no accessory claws (or serrate bristles) at tip of tarsi; male palpal organ with a tarsal hook; making irregular webs . . . . Linyphiidæ.

At base of mandibles there is no such roughened area, but usually a smooth swelling or boss: clypeus low, usually not as high as height of eye-area; accessory claws (or serrate bristles) at tip of tarsi; making geometric webs . . . . Epeiridæ.

24. Two eyes only in anterior row; clypeus not as high as ocular area 25.

Usually four eyes in front row, if but two, then clypeus is much higher than ocular area . . . . 26.

25. Eyes in four rows, the anterior practically at the clypeal margin, abdomen long and slender . . . . . . Podophthalmidæ.

Eyes not in four rows, the anterior row some distance from clypeal margin; P. M. E. closer to A. S. E. than latter to A. M. E.; body not long and slender . . . . Ctenidæ.

26. Males only: — eyes of second row very much larger than all other eyes together, abdomen long and linear . . . . . Dinopidæ.

Males only: — abdomen not long and linear, eyes not as above; head very low in front; at tips of tarsi are accessory claws as in Epeiridæ, leg I much larger and longer than others . . . . Uloboridæ.

Males and females: — Eyes of second row never so large; abdomen not linear; head rather high or else leg I not larger and longer than leg IV; no accessory claws at tips of tarsi . . . . . . 27.

27. But two eyes in anterior row, or if four, then median eyes are very small and fully three times their diameter from the side eyes; clypeus very high . . . . Oxyopidæ.

Four eyes in anterior row, middle eyes never so very much smaller nor so far from the side eyes; clypeus much lower . . . . 28.

28. Eyes in three rows, 4–2–2, those of anterior row very much smaller than others: cephalothorax rather long and narrow, clypeus nearly vertical; no spur at tip of tibia of male palpus . . . Lycosidæ.

Eyes in two curved rows, those of anterior row not so much smaller than others; the cephalothorax broad and flattened; clypeus often sloping; a spur at tip of tibia of male palpus . . . Pisauridæ.

29. Eyes in three rows, 4–2–2, those of second row very much larger than all other eyes together, abdomen very long and linear . Dinopidæ.

No such eye conditions; abdomen shorter . . . . . 30.

30. S. E. as far apart as M. E.; clypeus low; cephalothorax broad Uloboridæ.

S. E. closer to each other than are the M. E., clypeus high, or if low, then cephalothorax is not unusually broad . . . Dictynidæ.

31. Eyes plainly in three groups of two each; colored species . . 32.
Eyes in two groups of three each, or else all in one group; small, pale species . . . . 33.

32. A pair of stigmata just behind lung-slits; anterior legs large and heavy, never small species . . . . Dysderidæ.
No such stigmata; legs without spines, slender; male palpus at tip of tarsus, lip united to sternum . . . . Scytodidæ.

33. Cephalothorax broad and flat; legs long and slender, none of femora thickened, mandibles small . . . . Pholcidæ.
Cephalothorax more elongate, not flat; mandibles of normal size 34.

34. Legs with spines, and not slender; no cribellum; male palpus partly covered by tarsus, dark species . . . . . Agalenidæ.
Legs without spines, or else very slender; usually small and pale species 35.

35. Female with cribellum and calamistrum; male has palpal organ partly covered by tarsus; no shields on abdomen, legs without spines Dictynidæ.
Female without cribellum or calamistrum; male has palpal organ at tip of tarsus, wholly exposed . . . . 36.

36. Cephalothorax highest in front of middle; leg I long and stouter than others; three claws to each tarsus . . . . . Leptonetidæ.
Cephalothorax highest behind middle; femora IV thickened at base; two claws to each tarsus . . . . . . Oönopidæ.

Theraphosidæ.

Palpus arising from the outer basal side of the maxillæ . Atypinæ.
Palpus arising from near or at tip of maxillæ . . Theraphosinæ.

Atypinæ.

We have but one genus, Atypus, which is rare in the eastern States, with apparently two species. They live in silken tubes which extend some distance above the ground.

Theraphosinæ.

1. Tarsi with a third claw; no tuft or fascicle of hairs at tip . . 2.
Tarsi with but two claws, a fascicle of hairs at tip . . . 13.

2. Post-abdomen some distance above spinnerets; dorsal groove longitudinal; furrow of mandibles indistinct . . . . . . 11.
Post-abdomen just above spinnerets; dorsal groove transverse or elliptic; furrow of mandibles distinct . . . . 3.

3. Upper spinnerets rather short, last joint short and obtuse; mandibles with a cluster of teeth, or rastellum, in front . . . . . . 5.

Upper spinnerets long, and last joint slender: mandibles without rastellum . . . . 4.

4. Tarsi and metatarsi I partly scopulate; all tarsi unarmed Brachythele.

Tarsi and metatarsi I not scopulate: hind tarsi with spines Evagrus.

5. Tibia III with a deep sulcation above at base . . . . . 6.

No such sulcation . . . . 7.

6. Tip of abdomen broadly truncate, having an almost circular outline Cyclocosmia.

Tip of abdomen normal . . . . . . Pachylomerus.

7. Tarsi I and II not scopulate; with stout spines . Bothriocyrtum.

Tarsi I and II scopulate . . . . 8.

8. Sternal impressions large, close together, and far from margin Myrmeciophila.

Sternal impressions small and near the margin . . . . . 9.

9. Mandibles with four long, equal teeth in front forming the rastellum Actinoxia.

Rastellum of many irregular spines . . . . 10.

10. Tarsus I equal to metatarsus I, latter with only apical spines Amblyocarenum.

Tarsus I shorter than metatarsus I, latter with many spines Aptostichus.

11. With but four spinnerets . . . . . . Brachybothrium.

With six spinnerets . . . . 12.

12. Apical joint of upper spinnerets much longer than preceding; mandibles without a rastellum; no sternal impressions . . . Hexura.

Apical joint of upper spinnerets barely longer than preceding; mandibles with a rastellum; two pairs of small sternal impressions Atypoides.

13. Tibiæ and metatarsi III and IV with very few spines; tarsi shorter and broader . . . . 15.

Tibiæ and metatarsi III and IV with many spines; tarsi longer 14.

14. Metatarsi I scopulate to base, rarely with basal spines Eurypelma.

Metatarsi I not scopulate to base; basal spines present Rhechostica.

15. Eyes of anterior row scarcely unequal, forming a strongly procurved row . . . . Avicularia.

Eyes of anterior row distinctly unequal, forming a nearly straight row Tapinauchenius.

FILISTATIDÆ.

We have but one genus in this country, Filistata, and probably but one species, which is frequent about buildings in the southern States.

UROCTEIDÆ.

We have but one genus in this country, Thalamia Hentz, with two species in the South.

LEPTONETIDÆ.

1. The six eyes in two groups, four in a row in front, and two behind . . . Leptoneta.

The six eyes in three groups of two each, two in the middle and two each side . . . . 2.

2. S. E. form a diverging line, and touch by their sides . . Usofila.

S. E. touch at one point, and form a single opening within . . . Ochyrocera.

OÖNOPIDÆ.

Abdomen soft, globose . . . . Orchestina.

Abdomen with corneous shield, elongate . . Gamasomorpha.

SCYTODIDÆ.

1. With eight eyes; body dark . . . . . . Plectreurys.

With but six eyes . . . . 2.

2. Cephalothorax elevated behind, eye-groups widely separate; three claws to each tarsus; palpus of female with a claw at tip . . Scytodes.

Cephalothorax not elevated behind: eye-groups more approximate; palpus of female without claw at tip . . . . . . 3.

3. Three claws to each tarsus; anterior eye-row nearly straight: cephalothorax very slender . . . . Diguetia.

Two claws to each tarsus; anterior eye-row recurved: cephalothorax broader . . . . Loxosceles.

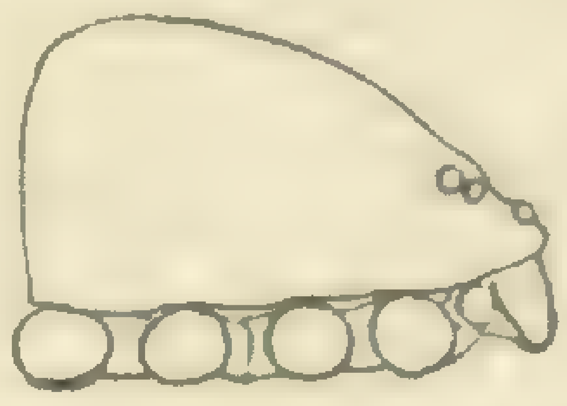

FIG. 6.—Cephalothorax of Scytodes.

PHOLCIDÆ.

1. With six eyes situated rather close together upon a prominent eminence . . . Modisimus.

Eyes not on an eminence, and in two groups . . . . . 2.

2. With but six eyes . . . . Spermophora.
With eight eyes . . . . 3.
3. A. M. E. much closer to each other than to A. S. E.; femora very long; abdomen elongate . . . . Pholcus.
A. M. E. as close to A. S. E. as to each other: abdomen globose 4.
4. Femur I not twice the length of cephalothorax, and shorter than femur IV . . . . Pholcophora.
Femur I twice as long as cephalothorax . . . . . . 5.
5. Posterior eye-row slightly procurved; femur I longer than IV Psilochorus.
Posterior eye-row slightly recurved; femur I shorter than IV Physocyclus.

DYSDERIDÆ.

1. Leg III directed backward; spines on sides of tibiæ IV; tarsi scarcely one fourth the length of metatarsi; no spines under metatarsi I Dysdera.
Leg III directed forward; no spines on sides of tibiæ IV; tarsi fully one third the length of metatarsi; spines under metatarsi I . . 2.
2. The M. E. rather closer to A. S. E. than to P. S. E. . . Segestria.
The M. E. closer to P. S. E. than to A. S. E. . . . Ariadne.

PRODIDOMIDÆ.

This is represented in our country by but one genus, Prodidomus Hentz, with one species, found in dark situations in houses in the southern States. An allied genus, Zimiris, occurs in Mexico, and differs from Prodidomus in having the inferior spinnerets very much longer than the others.

ZODARIIDÆ.

With but two distinct spinnerets; cephalothorax rather high; tarsi with 3 claws . . . . Lutica.
With more than two spinnerets; cephalothorax rather flat; tarsi with but two claws . . . . Homalonychus.

DRASSIDÆ.

1. Mandibles with a plate or lobe on under side behind the fang; posterior eye-row plainly recurved . . . . 2.
Mandibles without such plate, only one or two teeth; posterior eye-row often procurved or straight, rarely a little recurved . . . . . 3.
2. Posterior eye-row broader than anterior row; P. S. E. not much larger than P. M. E.; head broad . . . . Gnaphosa.

Posterior eye-row not broader than anterior row; P. S. E. plainly larger than P. M. E.; head narrow . . . . Callilepis.

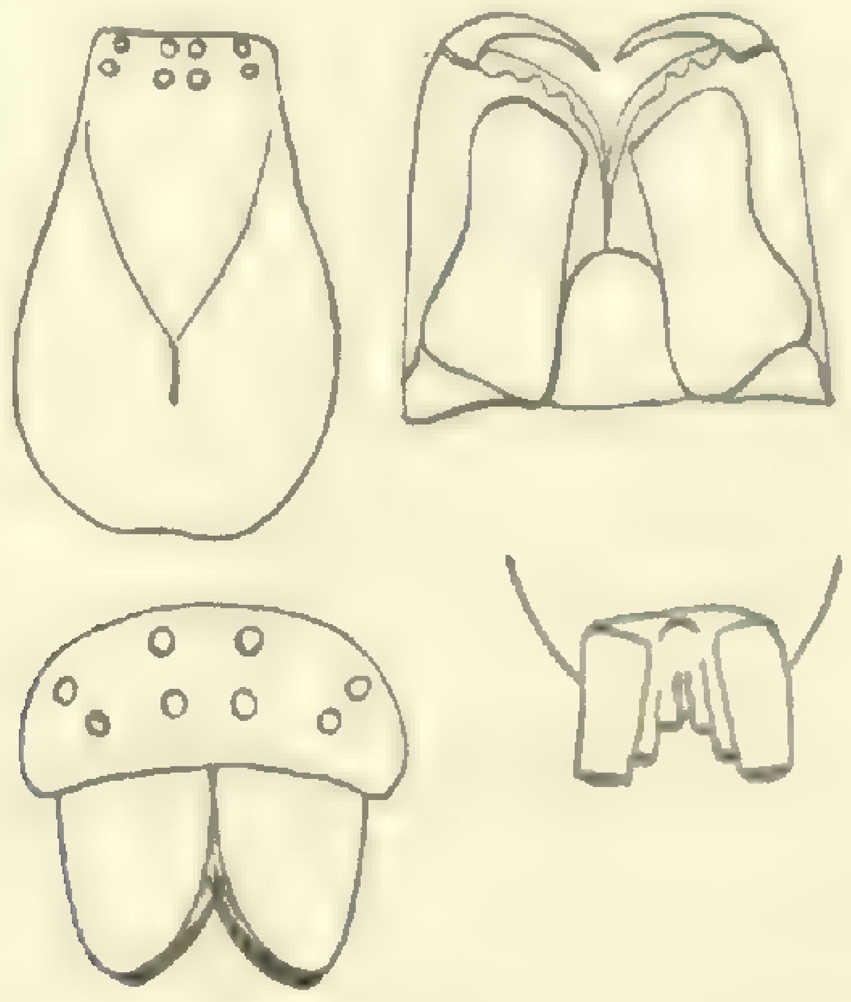

FIG. 7.—Drassidæ; face, cephalothorax, mouthparts, and spinnerets.

3. No dorsal groove; posterior eye-row slightly recurved: cephalothorax reddish yellow . . . . Sergiolus.
   Dorsal groove present, posterior eye-row rarely recurved . . 4.
4. P. M. E. much nearer to P. S. E. than to each other; cephalothorax and abdomen bivittate . . . . Cesonia.
   P. M. E. as near each other as to P. S. E., or at least, abdomen not bivittate . . . . 5.
5. Upper spinnerets plainly two-jointed, and longer than the lower pair; large dark-colored species; tarsi and metatarsi I, II, and III heavily scopulate . . . . Teminius.
   Upper spinnerets not plainly two-jointed and not longer than lower pair . . . . 6.
6. Posterior eye-row slightly recurved; P. M. E. widely separate; no spine above on base of tibiæ III and IV . . . . 7.
   Posterior eye-row straight or procurved . . . . . . 8.
7. Posterior eye-row plainly broader than anterior row; P. S. E. barely, if any, larger than P. M. E.; S. E. more than diameter apart Pœcilochroa.
   Posterior eye-row barely longer than anterior row; P. S. E. much larger than P. M. E.; S. E. not diameter apart; smaller spiders Eilica.
8. Posterior eye-row plainly procurved, P. M. E. oval . . . 9.
   Posterior eye-row little if at all procurved, and usually barely longer than anterior row . . . . 11.
9. Posterior barely longer than anterior row; P. M. E. approximate and larger than P. S. E. . . . . Megamyrmecion.
   Posterior row plainly longer than anterior row; P. M. E. rather widely separate . . . . 10.
10. Two spines above on tibiæ III and IV . . . . Drassodes.

No spines above on tibiæ III and IV . . . . . . Drassus.

11. P. M. E. large, oval, contiguous or nearly so ; no spine above on base of tibiæ III and IV; usually with but one or two spines below tibia I Zelotes.

P. M. E. smaller, nearly round, and plainly separate ; a spine above on base of tibiæ III and IV ; usually four to six spines below tibia I Herpyllus.

P. M. E. smaller, oval, well separated ; no spines above on base of tibiæ III and IV ; ten spines below on tibia I . . Drassinella.

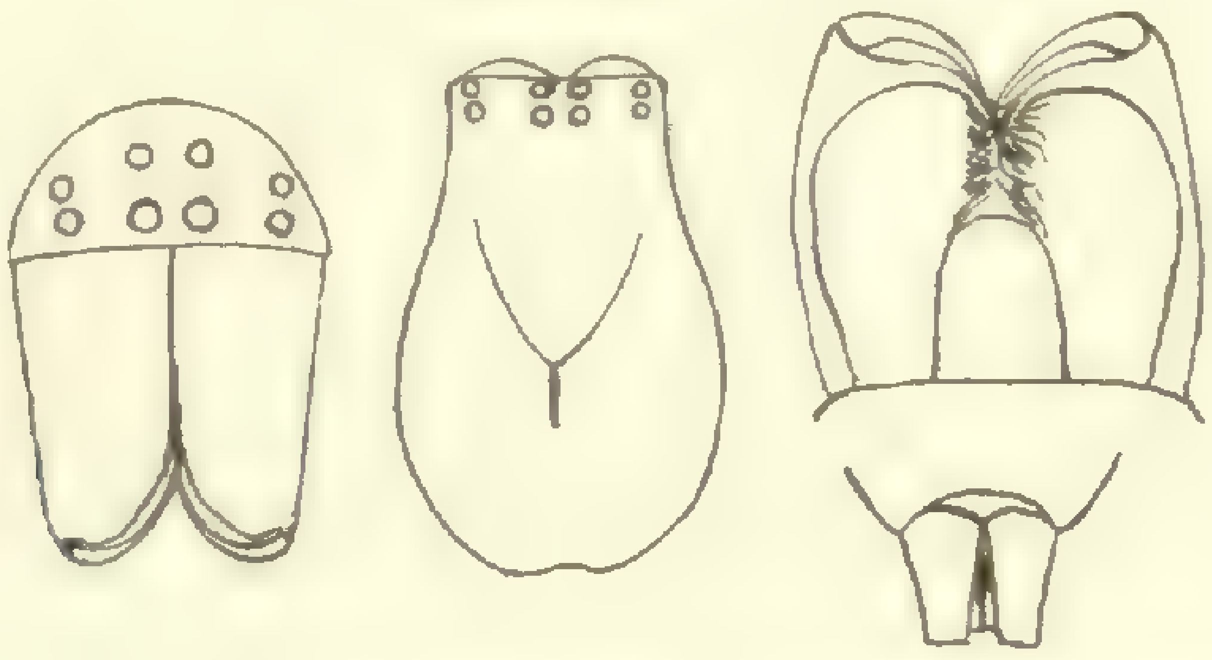

Fig. 8.—Clubionidæ ; face, cephalothorax, mouth-parts, and spinnerets.

Clubionidæ.

1. On the venter there is a transverse furrow, remote from spinnerets, representing the openings of the posterior spiracles . . . . . 10.

No such furrow remote from spinnerets . . . . 2.

2. Two rows of large spines under tibiæ I and II, more than two in each row . . . . 11.

Not more than 2–2 spines under tibiæ I and II, or else irregularly situate, and banded legs . . . . 3.

3. Maxillæ impressed with an oblique furrow, as in the Drassidæ, no dorsal groove . . . . Micaria.

Maxillæ without furrow, convex ; dorsal groove usually present . 4.

4. Leg I plainly longer than IV ; body and legs pale ; spines on legs Chiracanthium.

Leg I not longer than IV . . . . 5.

5. No spines on legs, or only a few under tibia I . . . . . 6.

Spines fairly numerous on legs . . . . 7.

6. Posterior eye-row strongly recurved . . . . . Trachelas.

Posterior eye-row straight . . . . Meriola.

7. A. M. E. several times their diameter from clypeal margin ; often a horny spot near base of abdomen ; legs usually partly dark Castaniera.

A. M. E. scarcely diameter from clypeal margin, no horny spot on abdomen, legs never dark . . . . 8.

8. Lip longer than wide ; mandibles long ; cephalothorax not mottled. Clubiona.

Lip broader than long; cephalothorax mottled with brown . . 9.

9. Anterior eye-row procurved . . . . Agrœca.

Anterior eye-row recurved . . . . Hilke.

10. The furrow at or before middle of venter; A. M. E. equal to A. S. E. Anyphæna.

The furrow behind the middle of venter; A. M. E. smaller than A. S. E. Gayenna.

11. Sternum broad, prolonged between hind coxæ: posterior eye-row not recurved, tibia I with five or six pairs of spines below . Phrurolithus.

Sternum not prolonged between hind coxæ which are nearly contiguous . . . . 12.

12. Posterior eye-row slightly procurved; five pairs of spines under tibia I Chemmis.

Posterior eye-row recurved . . . . 13.

13. But 3–3 spines under tibia I; two spines above on tibiæ III and IV Syspira

At least 5–5 spines under tibia I . . . . 14.

14. Eyes subequal in size: anterior eye-row recurved . Liocranoides.

Eyes unequal in size; anterior eye-row not recurved . . . 15.

15. A. M. E. smaller than A. S. E.: posterior row weakly recurved Apostenus.

A. M. E. larger than A. S. E.: posterior eye-row strongly recurved Zora.

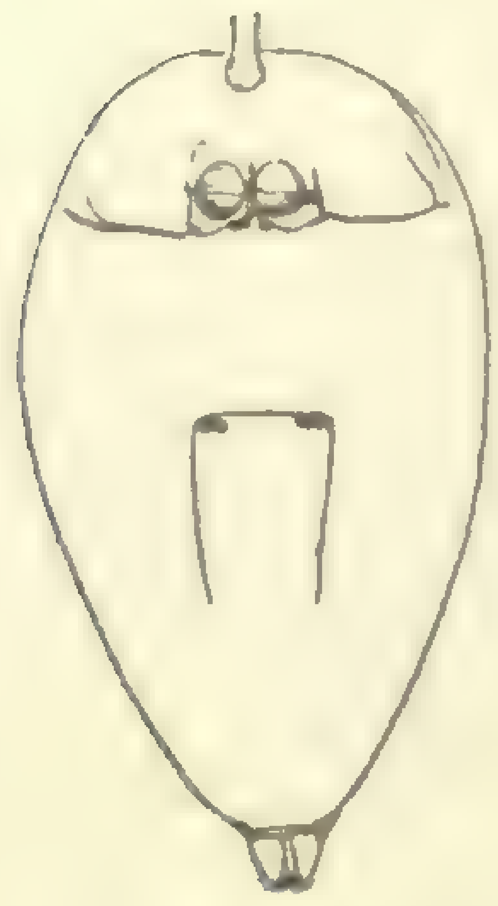

Fig. 9.—Venter of Anyphæna.

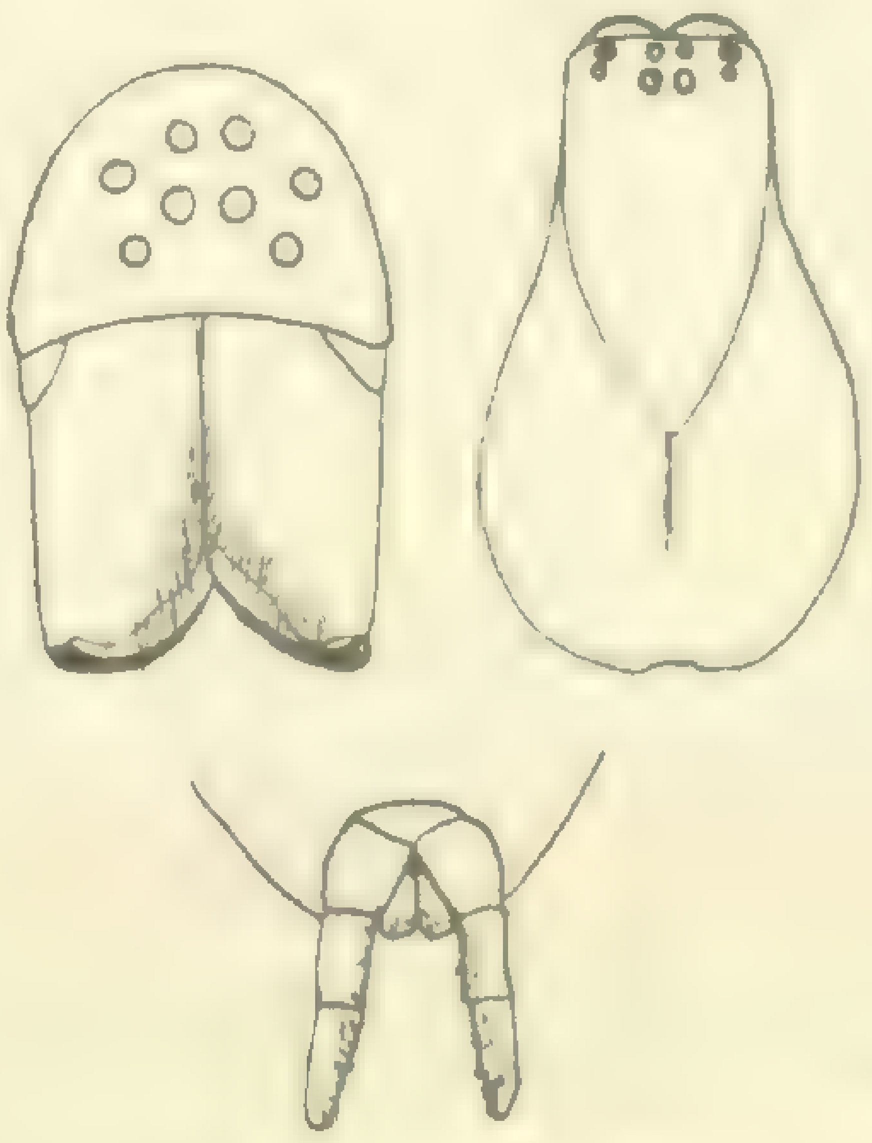

Fig. 10.—Agalenidæ; face, cephalothorax, and spinnerets.

Agalenidæ.

1. Spinnerets arranged in one nearly straight transverse row . Hahnia.

Spinnerets close together, in two rows . . . . . . 2.

2. But six eyes, the A. M. E. lacking . . . . . Chorizomma.

With eight eyes . . . . 3.

3. Both eye-rows very strongly procurved, so much so that the A. M. E. form a nearly straight line with the P. S. E.; cephalothorax narrow in front . . . . Agalena.

Both eye-rows not so strongly procurved . . . . . . 4.

4. A. M. E. much larger than any other eyes; quadrangle of M. E. as broad below as above . . . . Coras.

A. M. E. not larger than other eyes; quadrangle usually narrower in front . . . . 5.

5. Upper spinnerets of but one joint and not longer than lower pair; posterior eye-row straight or even a little recurved; tarsi I plainly more than one half as long as metatarsus; mandibles geniculate at base Cybæus.

Upper spinnerets of two joints and longer than lower pair . . 6.

6. Basal spine on outer side under tibiæ I and II not reaching to next spine; larger spiders . . . . 7.

Basal spine on outer side under tibiæ I and II reaches to next spine; smaller spiders . . . . 8.

7. Mandibles plainly geniculate at base; legs less slender . . Cœlotes.

Mandibles not or barely geniculate at base; legs very slender Tegenaria.

8. P. M. E. situated fully their diameter apart . . . . Cicurina.

P. M. E. less than diameter apart, and closer to the S. E. Cryphœca.

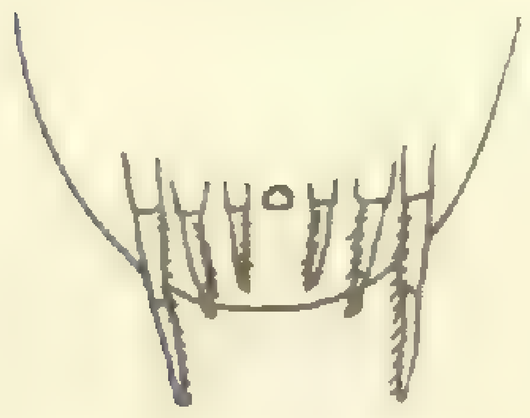

Fig. 11.—Spinnerets of Hahnia.

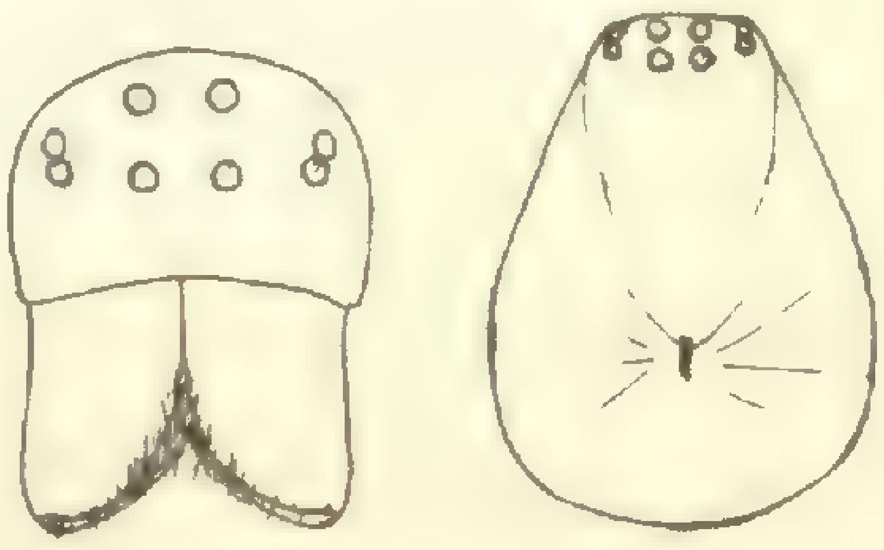

Fig. 12.—Theridiidæ; face and cephalothorax.

Theridiidæ.

1. Abdomen with hard skin and furnished with several humps; small species; sternum truncate behind . . . . Ulesanis.

Abdomen without humps and skin soft . . . . . . 2.

2. S. E. widely separate; posterior eye-row recurved . . . . 3.

S. E. contiguous or nearly so . . . . 4.

3. Leg IV as long as I; abdomen rather flat, and broad behind Epesinus.

Leg I longer than IV; abdomen globose . . . Lathrodectus.

4. P. M. E. fully four times their diameter apart; abdomen prolonged behind; leg IV about as long as I . . . . . . Spintharus.

P. M. E. rarely over twice diameter apart . . . . . 3.

5. A. M. E. larger than P. M. E. and much wider apart; clypeus rather high and concave; legs short, IV often as long as I; palpi thick in female . . . . 6.

A. M. E. rarely larger than P. M. E., if so then not wider apart . 7.

6. Abdomen pointed behind and somewhat flat . . . Euryopis.

Abdomen more globose, broadly rounded behind . . . Dipœna.

7. Cephalothorax with a transverse furrow in the middle; abdomen usually produced above behind, no chitinous pieces at base; leg I longer than IV . . . . 8.

Cephalothorax with only the ordinary dorsal groove or impression; abdomen not prolonged behind . . . . 9.

8. Abdomen very long and slender, vermiform . . . Ariamnes.

Abdomen much shorter . . . . Argyrodes.

9. On that part of the abdomen that overhangs the cephalothorax there is a chitinous curved piece each side, in the female not prominent, in the male much more so (they form a stridulating organ); colulus present. Leg I usually but little longer than IV; femur I rarely more than one and one fourth length of cephalothorax; leg IV usually longer than II . 10.

No such pieces on base of abdomen, colulus absent; leg I much longer than IV, which is often shorter than II; femur I usually one and one half to twice the length of cephalothorax . . . . . . 17.

10. Sternum broadly truncate between coxæ IV; small species Crustulina.

Sternum pointed behind; coxæ IV closer together . . . 11.

11. S. E. slightly, but distinctly separate, lower eye-row nearly straight; P. M. E. not large, and rather widely separate . . Lithyphantes.

S. E. contiguous . . . . 12.

12. P. M. E. plainly larger than A. M. E.; abdomen not black, with two yellow spots . . . . 13.

P. M. E. not larger than A. M. E. . . . . 14.

13. Leg IV a little longer than I, all short . . . Pedanostethus.

Leg IV plainly shorter than I, both long and slender . . Teutana.

14. A. M. E. much larger than A. S. E.; leg I longer than IV . Steatoda.

A. M. E. not larger than A. S. E. . . . . 15.

15. Leg IV plainly longer than I; sternum granulate . . Asagena.

Leg I a trifle longer than IV . . . . 16.

16. Femur I not one and one fourth as long as cephalothorax; abdomen rather depressed . . . . Enoplognatha.

Femur I nearly twice as long as cephalothorax; abdomen more slender, and in male, constricted near middle . . . . Coleosoma.

17. Sternum truncate between hind coxæ; tarsal claws with few or no teeth; leg I not much longer than IV . . . . 18.

Sternum pointed behind; hind coxæ more approximate; tarsal claws pectinate; abdomen usually globose; leg I often much longer than IV 23.

18. No shields or sigillæ on the abdomen . . . . 19.

Shields or sigillæ on abdomen . . . . 21.

19. Abdomen globose; cephalothorax short and high, narrow in front 20.

Abdomen elongate; cephalothorax broad in front; legs banded Ceratinops.[1]

[1] Ceratinops, new genus for *Ceratinella annulipes* Banks.

20. Tibia I not as long as cephalothorax ; cephalothorax very broad ; male eyes elevated . . . . Microdipœna.

Tibia I longer than cephalothorax, which is more elongate than preceding . . . . Mysmena.

21. Abdomen with shield across base . . . . . . Idionella.

Shield not across base . . . . 22.

22. Abdomen of both sexes with dorsal shield ; male with horn from eye-region ; no stiff bristles under femur I . . . . Histiagonia.

Abdomen of female without dorsal shield, only sigillæ ; male without frontal horn ; a row of stiff bristles under femur I . . Ancylorrhanis.

23. Anterior eye-row procurved ; tibia of male palpus large ; female with abdomen swollen in middle each side . . . . . Theridula.

Anterior eye-row straight or recurved ; tibia of male palpus not enlarged ; female not with swollen sides . . . Theridium.

LINYPHIIDÆ.

1. Cave spiders ; no claw at tip of palpus of female . . . . . 2.

Not cave spiders . . . . 4.

2. Without eyes ; sternum broad . . . . Antrobia.

With eyes . . . . 3.

3. P. M. E. about as close to P. S. E. as to each other ; A. M. E. barely diameter apart . . . . Phanetta.

P. M. E. much closer to each other than to P. S. E. ; A. M. E. several diameters apart . . . . Troglohyphantes.

4. No claw to tarsus of female palpus ; epigynum without a finger or hook ; male palpus with a tibial apophysis, usually but one spine above on tibia IV . . . . (Erigoninæ) 16.

A claw to palpus in female ; epigynum with a finger or hook ; male palpus without a tibial apophysis, although sometimes enlarged or a tooth at tip ; usually two spines or erect bristles above on tibia IV (Linyphinæ) 5.

5. Legs without spines ; mandibles long, and their lower anterior border provided with several long, slender teeth ; A. M. E. larger than P. M. E. Tapinopa.

Legs with at least a few spines, or not agreeing with above . 6.

6. Mandibles long, slender, divergent, in front with 3 pairs of long spines, abdomen depressed and rather broad ; P. M. E. less than diameter apart Drapetisca.

Mandibles without the 3 pairs of spines in front . . . . 7.

7. Tibiæ without lateral spines ; metatarsus I not longer than tibia I ; usually small spiders . . . . 8.

Tibiæ with lateral spines ; metatarsus I usually as long as, often longer than, tibia I ; larger spiders . . . . 9.

8. Posterior eyes closer together; S. E. on slight tubercles; legs long and very slender . . . . Microneta.
Posterior eyes farther apart; S. E. not on tubercles; legs less slender Tmeticus.
9. P. M. E. plainly closer to P. S. E. than to each other, and larger than S. E.; femora with few if any spines . . . . . . Neriene.
P. M. E. not closer to P. S. E. than to each other . . . 10.
10. No spines on metatarsi; P. M. E. rather close together Bathyphantes.
Spines on metatarsi, at least one . . . . 11.
11. P. M. E. very much larger than S. E., two or three times larger, about one diameter apart, and as far from very small S. E., which are no larger than A. M. E.; abdomen slender . . . . . Linyphiella.[1]
P. M. E. not much larger than other eyes . . . . . . 12.
12. P. M. E. at least two diameters apart, or else plainly farther from S. E. than from each other; quadrangle of M. E. plainly wider above than below . . . . Linyphia.
P. M. E. scarcely more than diameter apart, and about as close to P. S. E. . . . . 13.
13. All femora with some distinct spines . . . . 14.
All femora not with distinct spines . . . . 15.
14. Tarsus I two thirds of metatarsus I; quadrangle of M. E. rather narrower below . . . . Bolyphantes.
Tarsus I only one half of metatarsus I; quadrangle of M. E. as wide below as above . . . . Labulla.
15. Abdomen high and broad at base, tapering to a point behind Lepthyphantes.
Abdomen elliptical or even broader beyond middle, not tapering behind Frontinella.
16. Tarsus I only about one half as long as metatarsus I, male with lobate head . . . . Hypselistes.
Tarsus I two thirds or more of length of the metatarsus I . . 17.
17.[2] Dorsum of male abdomen with a corneous shield; often present also in female . . . . 18.
Dorsum of abdomen in both sexes without shield . . . 20.
18. Sternum broadly truncate and slightly concave behind between hind coxæ; usually some corneous pieces on venter: tarsi I but little shorter than metatarsi I . . . . Ceratinella.
Sternum less broad and somewhat convex behind between hind coxæ: no corneous pieces on venter . . . . 19.
19. Tarsi I plainly shorter than metatarsi; no hole in side of male head: P. M. E. but little higher than A. M. E. . . . . Exechophysis.

[1] Linyphiella, new genus for *Linyphia coccinea* Hentz.
[2] Beyond this the table is based on males, although females will frequently run to proper place.

Tarsi I about as long as metatarsi; a hole in side of head of male; P. M. E. much higher than A. M. E. . . . Lophocarenum.

20. Head of male with a horn from middle of eye-region; sternum rather elongate; posterior eye-row strongly procurved . . Cornicularia.

Head of male without such horn; sternum often broad, triangular 21.

21. Head of male plainly lobed, or at least with a hole in side behind S. E. 22.

Head of male not lobed, nor with a hole in side . . . . 26.

22. Metatarsus I of male swollen in middle . . . Caracladus.

Metatarsus I normal . . . . 23.

23. Male with two large and two small tufts of bristles in middle of eye-region; posterior eye-row very strongly procurved . Panamonops.

Male without such tufts; posterior eye-row but little procurved 24.

24. P. M. E. situate upon top of lobe of male . . . . . . 25.

Lobe of male not bearing eyes . . . . . . Dismodicus.

25. Sternum broad, triangular . . . . Diplocephalus.

Sternum more slender . . . . Walckenæra.

26. Male having a horn from middle of clypeus . . Delorrhipis.

Male without such horn . . . . 27.

27. Male palpus with enlarged femur; head of male elevated; posterior eye-row slightly recurved; legs slender . . . . . Gonatium.

Male palpus with femur normal . . . . 28.

28. A projection below at tip of tibia of male palpus; sides of cephalothorax often with teeth; posterior eye-row slightly recurved . Erigone.

No such projection to tibia of male palpus . . . . . 29.

29. S. E. situate on a slight elevation, making head broad in front; sternum rather broadly truncate behind between hind coxæ; tibia I shorter than the cephalothorax . . . . 30.

S. E. not on elevation; sternum narrowly, if at all, produced between hind coxæ . . . . 31.

30. Two rows of spines under metatarsus IV; female with large lateral spines under tibiæ and metatarsi I and II . . . . . Maso.

No rows of spines under metatarsus IV, nor under tibiæ and metatarsi I and II . . . . Ceratinopsis.

31. Tibia I longer than cephalothorax; legs very slender; sternum narrowly truncate between hind coxæ; head of male elevated Notionella.[1]

Tibia I shorter than cephalothorax . . . . 32.

32. Two rows of spines under tibiæ and metatarsi I and II Satilatlas.

No such spines under these joints . . . . 33.

33. P. M. E. closer to each other than to P. S. E.; a hump behind eye-region in male . . . . Grammonota.

Eyes of posterior row about equidistant; no hump behind eye-region . . . . 34.

[1] Notionella, new genus for *Ceratinopsis interpres.*

34. Distance between eyes of posterior row not much greater than diameter of an eye . . . . 35.
Distance between eyes of posterior row more than two diameters of an eye . . . . Acartauchenius.
35. Head of male elevated . . . . Tiso.
Head of male not elevated . . . . . . Gonglydium.

MIMETIDÆ.

Clypeus lower than ocular area ; hind legs much shorter than front legs ; lip much longer than broad . . . . Mimetus.
Clypeus as high as ocular area ; hind legs not much shorter than front legs ; lip but little longer than broad . . . . Ero.

FIG. 13.—Cephalothorax of Cornicularia.

FIG. 14.—Cephalothorax of Diplocephalus.

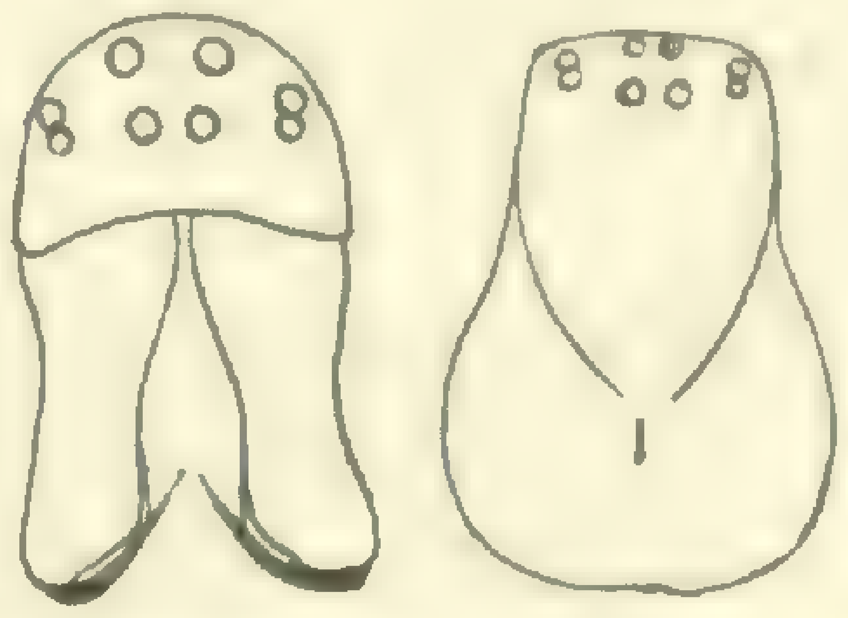

FIG. 15.—Dictynidæ; face and cephalothorax.

DICTYNIDÆ.

1. Legs without spines ; cribellum usually undivided in middle by a line . . . . 3.
Legs with spines ; cribellum divided by a line ; clypeus very low 2.
2. Maxillæ inclined over the lip ; hind legs unspined . Titanœca.
Maxillæ straight ; hind legs with spines . . . . Amaurobius.
3. With but six eyes ; colors pale . . . . . . Neophanes.
With eight eyes, but A. M. E. are sometimes very small . . 4.
4. Cribellum divided by a line in middle . . . . Dictynina.
Cribellum undivided . . . . 5.
5. A. M. E. very minute . . . . 6.
A. M. E. subequal to others . . . . 7.
6. A. M. E. higher than A. S. E. . . . . . . Dictyolathys.
A. M. E. between A. S. E. . . . . Prodalia.
7. Lip one third shorter than maxillæ . . . . . . Lathys.
Lip nearly as long as maxillæ . . . . Dictyna.

DINOPIDÆ.

We have but one genus, Dinopis, in this country, with one species ; a long and slender spider, not common throughout the southern States.

ULOBORIDÆ.

All eyes subequal in size, cephalothorax more elongate . Uloborus.

Eyes of posterior row very much larger than those of anterior row, in fact the A. S. E. are almost invisible . . . . . Hyptiotes.

EPEIRIDÆ.

1. Mandibles large, strongly divergent, abdomen and legs more or less elongate . . . . Tetragnathinæ.

Mandibles smaller, not strongly divergent . . . Epeirinæ.

FIG. 16.—Cephalothorax of Tetragnatha.

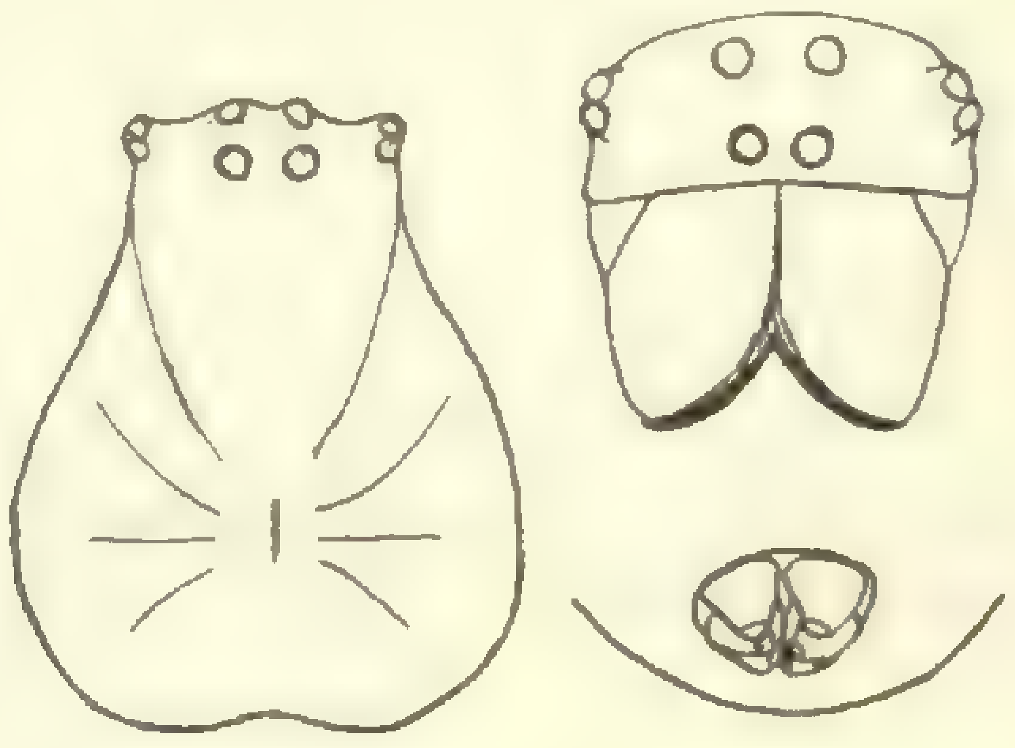

FIG. 17.—Epeiridæ; cephalothorax, face, and spinnerets.

Tetragnathiniæ.

1. Abdomen with a transverse ventral furrow near middle; abdomen not twice as long as broad . . . . Glenognatha.

Abdomen without such furrow . . . . 2.

2. Abdomen not twice (or barely) as long as broad, not much longer than cephalothorax . . . . Pachygnatha.

Abdomen three or four times as long as broad . . . . 3.

3. S. E. as close or closer than M. E. . . . . . Tetragnatha.

S. E. farther apart than M. E. . . . . 4.

4. Abdomen projecting beyond spinnerets in a tail . . . Eucta.

Abdomen not projecting beyond spinnerets in a distinct tail Eugnatha.

Epeirinæ.

1. Abdomen with a horny shield, or at least with sigillæ; leg IV longer than I . . . . 2.

Abdomen without shield or sigillæ: leg IV shorter than I . . 4.

2. Spinnerets enclosed at base by a horny ring; abdomen with spines 3.

Spinnerets not enclosed by horny ring; abdomen without spines Cercidia.

3. Cephalothorax as broad as long; abdomen broader than long . . . Gasteracantha.

Cephalothorax and abdomen longer than broad . . . Acrosoma.

4. Cephalothorax bearing spines or tubercles . . . Ordgarius.

Cephalothorax without spines or tubercles . . . . . 5.

5. Posterior eye-row strongly procurved: metatarsus plus tarsus I plainly longer than tibia plus patella I; cephalothorax rather flat . . . 6.

Posterior eye-row barely, if at all, procurved . . . . . . 7.

6. A. M. E. nearer to each other than to A. S. E., large species . . . Argiope.

A. M. E. as near to A. S. E. as to each other; small species Gea.

7. All metatarsi longer than tibia plus patella: abdomen subcylindric: maxillæ longer than broad; S. E. separate by fully two diameters; legs often with bands of erect hair . . . . Nephila.

Metatarsi shorter than tibia plus patella, rarely equal in fore legs: when so, then maxillæ shorter than broad, S. E. approximate, and no bands of erect hair on legs . . . . 8.

8. Hind femora with a fringe of curved hairs at base: abdomen subcylindric; S. E. approximate; P. M. E. only about twice as far from P. S. E. as from each other; legs very slender and with only a few slender spines . . . Leucauge.

Hind femora without such fringe of erect, curving hairs at base 9.

9. Cephalothorax much elevated behind, sloping forward to eye-region 10.

Cephalothorax not prominently elevated behind . . . . . 11.

10. Legs with long spines; P. M. E. less than diameter apart; no tubercles on abdomen . . . . Mangora.

Legs without spines, or very weak ones: P. M. E. fully two diameters apart; abdomen with tubercles . . . . . . Carepalxis.

11. Abdomen with a median hump or cone at base, as well as lateral projections; sternum rather long; clypeus high . . . . Plectana.

Abdomen without median together with lateral projections . . 12.

12. S. E. separated by fully diameter and on separate tubercles . 13.

S. E. contiguous or nearly so, at least upon the same eminence . 14.

13. P. M. E. small and close together; mandibles slender . . . Dolichognatha.

P. M. E. equal to others and widely separate . . . Azilia.

14. P. M. E. scarcely more than one and a half diameter apart, and as close to the P. S. E. as to each other: S. E. slightly separate; all eyes subequal in size; epigynum without a finger . . . . . . 15.

P. M. E. much closer to each other than to P. S. E. . . . 18.

15. Tarsus IV with many serrated bristles beneath: small spider with globose abdomen . . . . Theridiosoma.

Tarsus IV without serrate bristles beneath: larger species: abdomen not globose . . . . 16.

16. Maxillæ twice as long as broad; mandibles long and slender; abdomen convex above . . . . Meta.
Maxillæ not twice as long as broad . . . . 17.
17. Abdomen elliptical, rather depressed, without humps at base Zilla.
Abdomen subcylindric, with two small humps at base . . Hentzia.
18. No spines above on tibiæ I and II . . . . 19.
With some spines, at least one, above on tibiæ I and II . . 20.
19. Abdomen with spines or humps; cephalothorax broad and tumid in front . . . . Wagneriana.
Abdomen without spines or humps . . . . . Metazygia.
20. Legs very slender, especially leg I, almost destitute of spines; cephalothorax very slender; posterior eye-row strongly recurved Acacesia.
Legs less slender and with a number of distinct spines, or else the posterior eye-row not strongly recurved . . . . 21.
21. Abdomen pointed at base, elongate, sternum one and one half longer than broad; P. M. E. scarcely diameter apart . . . Larinia.
Abdomen not pointed in middle at base . . . . . . 22.
22. Abdomen as high behind middle as at base, and elliptical in outline or broader behind middle; P. M. E. about diameter apart; epigynum without finger; small species, with short legs . . . . . Singa.
Abdomen highest toward base, and usually broadest near base . 23.
23. Cephalothorax with a broad transverse furrow (at least in female); abdomen usually prolonged above behind; A. S. E. never twice as far from A. M. E. as latter from each other; quadrangle of M. E. plainly wider below than above; legs more hairy . . . . . Cyclosa.
Cephalothorax without such furrow; abdomen rarely prolonged above behind; legs more spiny . . . . Epeira.

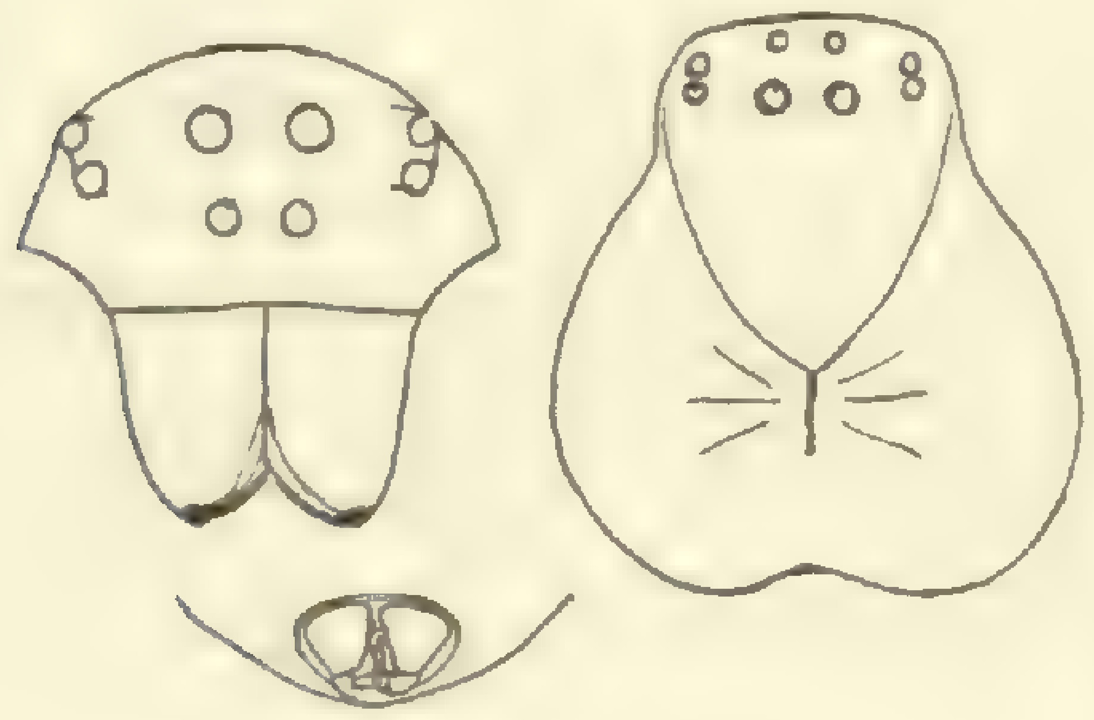

FIG. 18.—Thomisidæ; face, cephalothorax, and spinnerets.

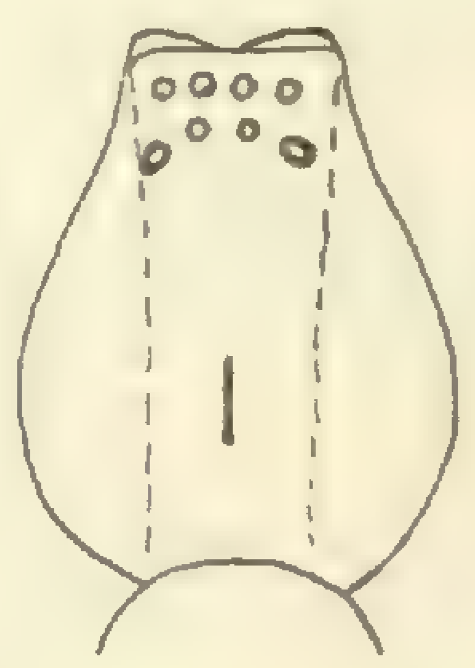

FIG. 19.—Cephalothorax of Pisaurina.

THOMISIDÆ.

1. Legs III and IV not or scarcely shorter than legs I and II; tarsi I and II scopulate (at least in females); hairs of body usually branched, prone not erect . . . . (Philodrominæ) 2.

Legs III and IV much smaller than I and II; tarsi I and II not scopulate; hairs of body, simple, scattered, and erect. (Misumeninæ) 7.

2. Leg II very much longer than I; posterior eye-row almost straight; cephalothorax broad . . . . Ebo.

Leg II but little longer than I; posterior eye-row very plainly recurved 3.

3. Five pairs of spines under tibiæ I and II; P. M. E. nearer to P. S. E. than to each other . . . . Philodromoides.

Less than 5–5 spines under tibiæ I and II . . . . 4.

4. P. M. E. farther apart than from P. S. E.; abdomen not very slender; leg IV shorter than leg I . . . . Philodromus.

P. M. E. not nearer P. S. E. than to each other, or if barely so then leg IV is longer than I . . . . 5.

5. P. M. E. much nearer to each other than to P. S. E.; abdomen long and slender; leg IV longer than I . . . . Tibellus.

P. M. E. about as near P. S. E. as to each other . . . . 6.

6. Leg IV shorter than leg I . . . . Apollophanes.

Leg IV longer than leg I . . . . Thanatus.

7. Legs I and II with spines only under tibiæ and metatarsi, at most with one or two very minute ones elsewhere . . . . 8.

Legs I and II with distinct spines elsewhere . . . . . 10.

8. Abdomen furnished behind with two prominent conical projections Thomisus.

Abdomen without two projections behind . . . . . . 9.

9. A ridge between eye-rows . . . . Runcinia.

No ridge between eye-rows . . . . Misumena.

10. Abdomen high and pointed behind: clypeus sloping; tubercle at P. S. E. much larger than at A. S. E. . . . . Tmarus.

Abdomen broadly rounded behind: clypeus more vertical: tubercles of S. E. subequal in size . . . . 11.

11. Cephalothorax very flat; dark colored species . . . Coriarachne.

Cephalothorax moderately high . . . . 12.

12. Abdomen, cephalothorax, and legs pale whitish or yellowish, but little marked except bands on legs of males . . . . . Misumessus.

Abdomen, or cephalothorax and legs, dark, or heavily marked with dark . . . . 13.

13. Quadrangle of M. E. higher than broad: tibiæ I and II with 2–2 spines . . . . Ozyptila.

Quadrangle of M. E. not higher than broad . . . . . 14.

14. Eyes of lower row equidistant: A. M. E. larger than P. M. E.: tibiæ I and II with 3–3 spines . . . . Synæma.

A. M. E. nearer to A. S. E. than to each other, and not larger than P. M. E.; tibiæ I and II with 4–4 or 5–5 spines . . . Xysticus.

SPARASSIDÆ.

1. P. S. E. in a row with anterior eyes; tarsal claws smooth; cephalothorax extremely flat . . . . Selenops.
   P. S. E. behind anterior row; tarsal claws toothed; cephalothorax plainly arched . . . . 2.
2. P. S. E. much larger than P. M. E. . . . . Heteropoda.
   P. S. E. barely, if at all, larger than P. M. E. . . . . Olios.

PISAURIDÆ.

Anterior eye-row recurved; quadrangle of M. E. broader behind than high; clypeus about as high as quadrangle of M. E. . Dolomedes.
Anterior eye-row straight; quadrangle of M. E. not broader behind than high; clypeus not as high as quadrangle of M. E. . . Pisaurina.

PODOPHTHALMIDÆ.

Area outlined by four anterior eyes is much wider than long Thanatidius.
Area outlined by four anterior eyes is as long as wide Maypacius.

CTENIDÆ.

A. S. E. nearer to A. M. E. than to either P. S. E. or P. M. E. Titiotus.
A. S. E. nearer to P. M. E. or to P. S. E. than to A. M. E. Ctenus.[1]

LYCOSIDÆ.

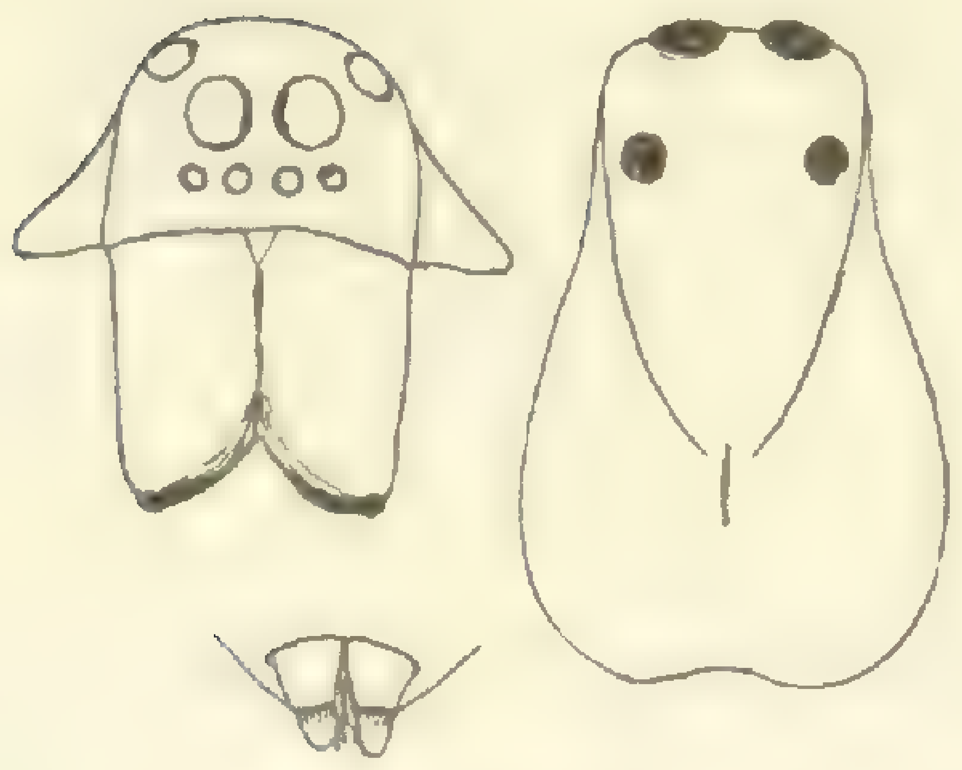

FIG. 20.— Lycosidæ; face, cephalothorax, and spinnerets.

FIG. 21.—Oxyopidæ; face and cephalothorax.

[1] This includes Cupiennius and Anahita; they differ from Ctenus only by minute or slight characters difficult of verification. Titiotus is unknown to me.

1. Tibiæ III and IV with a stout spine at base above . . . . 4.
Tibiæ III and IV without spine at base above, although there may be one near middle above . . . . 2.
2. No spines above on tibiæ III and IV; long hair above on these joints, head large and high . . . . Geolycosa.
A spine near middle above on tibiæ III and IV . . . . 3.
3. Upper spinnerets not longer than lower; anterior eye-row not wider than the second . . . . Trochosa.
Upper spinnerets longer than lower; anterior eye-row wider than second row; tarsi heavily scopulate . . . . Sosippus.
4. Cephalic region with a wedge-shaped mark, containing a central stripe; posterior spinnerets longer than others; eyes of second row scarcely their diameter apart, small species . . . . Pirata.
No such mark on cephalic region; spinnerets subequal in length 5.
5. Tibia I with 4–4 imbricated spines, the basal ones reaching beyond base of second ones beyond; very small species; eyes of second row not their diameter apart . . . . Trabea.
Basal spines on tibia I not reaching beyond base of the third pair, usually but 3–3 spines below . . . . 6.
6. Cephalothorax without median mark of any kind; spines under tibia I very short, 3–3 . . . . Allocosa.
Cephalothorax with a paler median stripe or mark . . . . 7.
7. Head with sloping sides, eyes of second row usually scarcely diameter apart; usually 3–3 short spines under tibia I, the basal pair rarely reaching next pair; lip longer than broad; larger spiders . Lycosa.
Head with more vertical sides; eyes of second row more than diameter apart; 3–3 long spines under tibia I, the basal pair usually reaching next pair; lip not longer than broad; smaller spiders . . Pardosa.

Oxyopidæ.

1. Posterior eye-row only slightly procurved; mandibles higher than height of cephalothorax in front; large greenish spiders . Peucetia.
Posterior eye-row strongly procurved; mandibles scarcely as long as height of cephalothorax in front . . . . 2.
2. P. M. E. much closer to P. S. E. than to each other . Hamataliva.
P. M. E. about as close to each other as to P. S. E. . Oxyopes.

Attidæ.

1. Abdomen more or less constricted; cephalothorax usually constricted; pedicel distinctly chitinized . . . . 2.
Neither cephalothorax nor abdomen constricted; pedicel soft . 4.

2. Leg I plainly thicker than the other legs; cephalothorax only slightly constricted . . . . Peckhamia.
Leg I as slender as others . . . . 3.

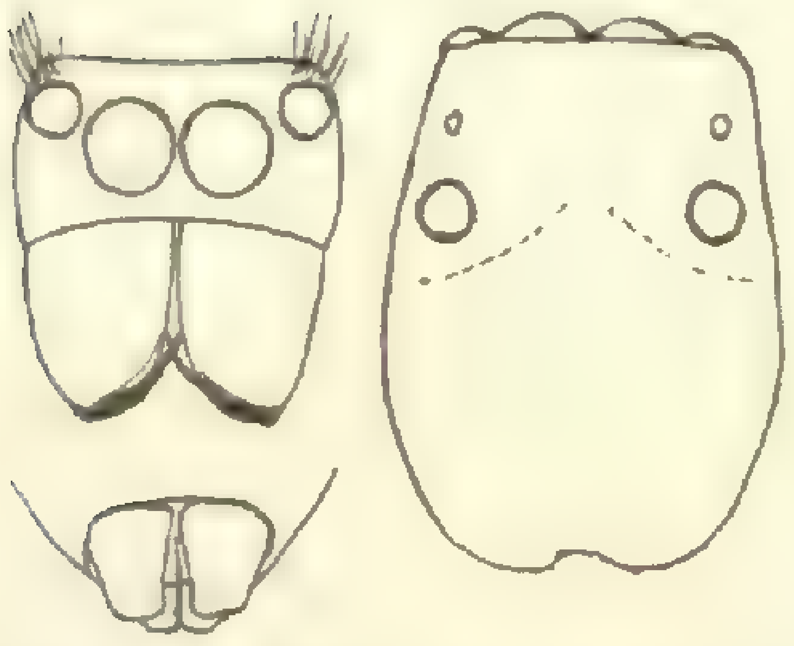

FIG. 22.— Attidæ; face, cephalothorax, and spinnerets.

FIG. 23. — Attidæ; two types of spine-arrangement under tibia I.

3. Cephalothorax and abdomen very strongly constricted; apical joints of female palpus slender . . . . Synemosyna.
Cephalothorax and abdomen but little constricted; apical joints of female palpus enlarged . . . . . . Myrmarachne.
4. Eyes in four rows; pale green spiders . . . Lyssomanes.
Eyes in three rows . . . . 5.
5. No spines under tibia I, or at most with one or two small ones 6.
Several spines under tibia I . . . . 9.
6. Cephalic part very long, reaching almost to base of abdomen; leg I plainly thickened . . . . Homalattus.
Cephalothorax slopes from before middle to base . . . 7.
7. Leg I plainly heavier than others . . . . 8.
Leg I slender, as the others . . . . Salticus.[1]
8. No spines on hind legs . . . . Admestina.
A few distinct spines on hind legs . . . . . . Eremattus.
9. Leg III as long as or longer than IV, at least in males; usually spines on sides of patellæ III and IV; coxæ I separate by more than width of lip; 2–2 or 3–3 spines under tibia I; legs usually quite hairy . 30.
Leg III plainly shorter than IV . . . . 10.
10. Ocular area occupying fully one half of the cephalothorax, the dorsal eyes situated at its greatest width, and projecting laterally Zygoballus.
Ocular area occupying less than one half of the cephalothorax; or if so, then the cephalothorax is not plainly broader at dorsal eyes than elsewhere . . . . 11.
11. Tibia I with 4–4 spines below (or less), the basal one of inner series is nearer to base than the first third of tibial length . . . . 12.

[1] Latreille in 1810 fixed type of this genus as *S. scenicus*.

Tibia I with 3–3 spines (or less), the basal one of inner series situate one third of tibial length (or greater distance) from base; coxæ I usually widely separate . . . . 22.

12. Metatarsus IV heavily spined near base and middle, both below and on sides; cephalothorax never very low, nor very broad; usually spines on patellæ III and IV . . . . 17.

Metatarsus IV spined only at tip, or with one or two weak spines on sides; never a basal and middle circle of spines . . . . . 13.

13. Coxæ I approximate; leg I plainly thickened; sternum usually long; usually large species . . . . 15.

Coxæ I widely separate; leg I barely thickened; sternum short; very small species, with a narrower cephalothorax . . . . . 14.

14. Ocular area occupying nearly one half of cephalothorax; as wide in front as behind, dorsal eyes as large as laterals of first row; no spines below on tarsus IV . . . . Neon.

Ocular area less than one half of cephalothorax, rather wider behind; dorsal eyes smaller than laterals of first row; spines below on tarsus IV Attidops.

15. Abdomen about four times as long as broad; tibia I with 4–4 spines below . . . . Hyctia.

Abdomen much shorter . . . . 16.

16. Eye-region occupying two fifths of cephalothorax; the sternum nearly as broad as long, smaller species . . . . . . Fuentes.

Eye-region occupies about one third of cephalothorax; the sternum much longer than broad; larger species . . . . . Marpissa.

17. Tibia I with 4–4 spines below . . . . 18.

Tibia I with less than 4–4 spines below . . . . . . 19.

18. Ocular area slightly narrower behind than in front; leg IV plainly longer than I . . . . Mævia.

Ocular area barely narrower behind, leg I as long as IV Plexippus.

19. Cephalothorax rather long; eye-area occupying scarcely one third of length; tibia I with 3–3 spines . . . . 20.

Cephalothorax shorter; eye-area occupying fully two fifths of length; coxæ I widely separate . . . . 21.

20. Basal spine of femora III and IV about one half as long as the joint; abdomen vittate . . . . Phlegra.

Basal spine of femora III and IV much shorter; abdomen not vittate . Sidusa.

21. Patella III as long as IV, no patellar spines . . . . Euophrys.

Patella III shorter than IV, patellar spines present . . . Attus.

22. Cephalic part about two thirds of cephalothorax, reaching almost to abdomen; legs short, leg I thickened; hind metatarsi spined only at tip Homalattus.

[1] Attidops, a new genus for *Ballus youngi* Peck.

Cephalic part far shorter . . . . 23.

23. Cephalothorax high, and rather broad; quadrangle of eyes wider behind than in front; large species, rarely under 7 mm.; leg I heavy and very hairy, often with fringes of hair, mandibles often iridescent; often a group of stout bristles near lateral eyes . . . . Phidippus.

Cephalothorax not as high and heavy, leg I not so hairy; smaller species, rarely over 6 mm. . . . . 24.

24. A spine above before middle on tibia III and IV, and above on base of metatarsus IV; leg I not thickened; small species . . Attinella.[1]

No spines above on tibia III and IV, nor on base of metatarsus IV 25.

25. Tibia I with 2–2 large spines, and toward base are two pairs of large bristles with enlarged bases, not obscured by other hairs; metatarsi IV spined throughout, patellæ III and IV with spines; leg I not much thickened . . . . Thiodina.

Tibia I without such bristles, distinct from all else, 3–3 spines below 26.

26. Legs with few hairs (except sometimes a brush under tibia I in male), tibia I about three times as long as broad, with very small spines; legs lineate with dark . . . . Tutelina.

Legs more hairy, tibia I much stouter; legs not lineate (or rarely) with dark . . . . 27.

27. Cephalothorax much broader than width of dorsal eye-line; tibia and metatarsus I in male elongate; abdomen quite slender; leg I not very heavy; legs III and IV not plainly banded . . . . . Wala.

Cephalothorax narrower at dorsal eyes; tibia and metatarsus I not elongate in male . . . . 28.

28. Cephalothorax plainly depressed; leg I very much thickened, male with horny shield on base of abdomen . . . . . Metacyrba.

Cephalothorax higher; male without shield at base . . . . 29.

29. Tibia I plainly convex below; legs less hairy; cephalothorax longer Icius.

Tibia I barely convex below; legs more hairy; cephalothorax shorter Dendryphantes.

30. Very few spines on hind legs, none above on bases of tibiæ III or IV, nor on base above of metatarsus III; quadrangle of eyes wider in front; smaller, less hairy species . . . . . Habrocestum.

Hind legs with many spines, often one above on base of either tibia III or IV or both, and a spine above on metatarsus III; quadrangle of eyes usually wider behind . . . . Pellenes.

[1] Attinella, a new genus for *Attus dorsatus* Banks.

[2] Includes Evarcha Simon; our one species (which seems to be the same as the *E. paleata* of Europe) cannot be readily separated by generic characters from some Pellenes.

PAPERS ON CLASSIFICATION OF AMERICAN SPIDERS.

BANKS, N.

'92. A Classification of the North American Spiders. *Can. Entom.*, vol. 24, pp. 88–98.

CAMBRIDGE, F. O. P.

'97–:05. Arachnida-Araneida, vol. 2. *Biologia Centrali-Americana*, London.

COMSTOCK, J. H.

:03. A Classification of North American Spiders. Ithaca, N. Y.; 55 pp.

PECKHAM, G. W. and E. G.

'88. Attidæ of North America. *Trans. Wisc. Acad. Sci.*, vol. 7, 104 pp.

SIMON, E.

'97–:04. Histoire naturelle des araignées. Paris; 2d ed., 2 vols.

THORELL, T.

'69–'70. On European Spiders. Upsala; 240 pp.

BIOLOGY OF *ACMÆA TESTUDINALIS* MÜLLER.

M. A. WILLCOX.

Acmæa testudinalis Müller, the tortoise-shell limpet, as it is called by Forbes and Hanley, is the common limpet of our New England shores. It, together with its variety *alveus*, is the sole representative on this coast not only of its genus and family but of the entire group of the Docoglossa and by far the most convenient example of the suborder Diotocardia, which includes all the more primitive Gasteropods. It is abundant and accessible, it is easily kept alive in aquaria, and living as it often does in tide-pools, is conveniently observed under its natural conditions. But in spite of these facts it has never been made the subject of careful study.

I am at present engaged upon a paper which is intended to supply this lack and from which I excerpt the following biological notes.

Acmæa is a large genus whose eighty-four species are widely scattered over both northern and southern hemispheres. Representatives have been recorded not only from both eastern and western shores of all the great continents except Africa,[1] but from Australia, from New Zealand, and from many islands of the Atlantic and Pacific including some which are oceanic. The genus is at present arranged only tentatively. "More than any other shells, these must be studied with constant reference to not only habitat geographically, but *station* as well. For an exact knowledge of the group we must therefore wait until observations on the species are made with special reference to their modes of life and surroundings" (Pilsbry). It seems probable, moreover, that a careful comparative study of the different species might throw light upon various questions of geographical distribution. This statement of the final aim of

[1] Two species only are as yet recorded from this continent: one from Natal and one from Cape Town.

the investigation may serve to explain the presence in these notes of material that might otherwise seem trivial. It is believed that nothing has been admitted which does not bear on the general question.

Limpets are found on the entire New England coast and northward to the Arctic Ocean. Comparatively rare and local south of Cape Cod, they increase in numbers and in size as one passes northward until at Eastport, Maine, they are one of the most abundant of the littoral molluscs. They are found between tide-marks in pools and also in such shaded places as provide them at once with coolness and moisture. The vertical face of a rock heavily hung with dripping Fucus or the under surface of the larger beach pebbles are attractive spots. Although they are to be found occasionally where the water is at least slightly fouled by sewage, as in the estuary at Beverly, they are far more abundant in that which is clean and pure.

So far as reported they seem to reach their maximum size in the region of Eastport, which is bathed by the cool waters of the Arctic current. On the Massachusetts coast a limpet an inch long is a giant but at Eastport they not rarely reach a length of 32 mm. The first explanation of this fact which presents itself is of course that the cooler water presents the optimum temperature for these animals; this is not, however, the only possible explanation. The Arctic current is not only cooler but more equable in temperature than more southern waters. At Eastport the maximum yearly variation in temperature of the water is about 12° C. (32.5°–54° F.): at Boston it is nearly 23° C. (29°–70° F.).[1] Limpets living entirely below tide-mark would therefore enjoy comparatively equable temperature conditions at Eastport. This would not, however, be true for those living between tide-marks, for the annual variation in temperature of the air at Eastport is often as much as 35° C. (4°–67° F.) — 10° C., it may be, in a single month. Bathed twice a day by the water, exposed twice a day to the air, such individuals in spite of the comparatively cool places which they affect, would be exposed to condi-

[1] These figures are deduced from the records of the U. S. Weather Bureau at Eastport and Boston, for the years 1887–89, the only years during which observations of water temperature were made.

tions probably at least as variable as those of the Massachusetts waters. If now we examine their size with reference to their habitat, we find that the limpets of Eastport are large only when living at or near the low-water mark of spring tides so that they are rarely or never left uncovered by the sea, and that higher up on the beach the animals though no less abundant are of smaller size, no larger in fact than with us. We find also that in Massachusetts there is no marked difference in size between limpets which are continuously submerged and those which live between tide-marks. The conclusion is therefore forced upon us that size in these animals is correlated not necessarily with a low but with an equable temperature. The advantage of uniform thermal conditions was long ago pointed out by Möbius and Semper.

In the late autumn, limpets in the neighborhood of Boston either altogether disappear or become very scarce, reappearing in numbers in March or April. In Eastport, however, they remain near the shore for the entire year. Their disappearance from the Massachusetts coast is probably due to a retirement to deeper water; this is, I am told by Professor S. I. Smith, the practice among several of our littoral animals. Limpets will stand a good deal of cold; Miss Annie Sullivan, an observant and intelligent collector who is familiar with the animals at Eastport, tells me that she has revived them after ice had formed within the shell and found them apparently no worse for the experience. It seems very probable therefore, that when they withdraw in the autumn they go only a little below tide-mark, thus avoiding the very considerable daily variation in temperature to which they would often be subjected if they remained above the low-water line.

The distribution of limpets as given above is taken from Smith and Verrill's "Invertebrate Animals of Vineyard Sound," a work which was published nearly thirty-five years ago. I am not aware that any investigations have been undertaken since that time which would show whether it is still correct. Forbes and Hanley described this species in 1853 as having, at least in Great Britain and Ireland, a tendency to migrate southward and Forbes had already described its sudden appearance nearly

twenty years before on the northern shore of the Isle of Man, where it is still to be found. In view of these facts it would be very interesting to learn whether it is moving southward on our own coast.

Distribution of the adult animal is probably effected not only through its own locomotion but also by the aid of tides and currents. On one occasion, though only on one, I found a limpet crawling back downward on the surface film like a fresh-water snail but I have not very infrequently found them clinging to floating pieces of the larger Floridiæ, upon which they feed. It will be remembered that Nacella and Helcioniscus live habitually upon the large fronds of Macrocystis. Occasional transportation of the adult by such means may not impossibly be a more effective factor in its distribution than the brief pelagic life of the young, which Boutan found in the case of *A. virginia* to be limited, at least in the waters of Roscoff, to a few days' duration.

Locomotion is almost exclusively effected by crawling over the substratum. Progress is exceedingly slow; the fastest crawling of which I have record was at the rate of about three inches per minute. This was in a tide pool where the animal was undisturbed and in natural conditions. Under such circumstances it often remains motionless for hours. In captivity it is not unusual to find one limpet crawling over another or adhering to its shell, although in such circumstances I have never observed either individual showing any recognition of the presence of another of its own kind.

In view of the well known homing habits of Patella and of the fact that I have found the same power possessed at least in a limited degree by animals so widely separated as *Fissurella barbadensis* Gmelin and *Siphonaria alternata* Say, I have made repeated attempts to satisfy myself of its existence in Acmæa. These attempts have, however, been unsuccessful. The difficulty lies in the character of the rocks of the New England coast, which are unsuited either to the formation of a sunken "scar" like that which indicates the home of Patella or of a discolored spot like that produced by Siphonaria. It is therefore impossible to locate with certainty the "home" of a limpet, which

is the first step in determining whether or not it possesses the homing power. Dr. W. H. Dall, however, tells me that he has observed on the Pacific coast individuals of *Acmæa spectrum* Reese whose shell margins exactly corresponded to the irregularities of the soft rocks on which they live. Fisher notes that both this and other species of Acmæa are often found adhering to the shells of Lottia in which they have made shallow depressions. These observations furnish the strongest presumptive evidence that in some species, at all events, the homing power is present and render desirable the investigation of the question in *Acmæa testudinalis* under conditions more favorable than those afforded by the New England coast.

The food of limpets appears to be exclusively vegetable. A freshly taken specimen always has the digestive tract stuffed with a finely divided mass of unrecognizable material mingled with which are unicellular algæ and bits of the cortical cells of some of the larger ones. I have made no attempt to identify these organisms. Intermixed with this material are great numbers of tiny stones which probably, like those found in a bird's gizzard, aid in the comminution of the food. This is especially necessary in the limpet since for the greater part of their extent the walls of the alimentary tract are entirely devoid of muscles. These bits of stone are very likely, at least in large measure, fragments rasped off by the radula from the rocks together with the small algæ which cling to them. It has been suggested in regard to Patella that the bits of alga cortex are in like fashion detached, so to speak, by accident together with minute organisms both animal and vegetable, which live upon the alga and which constitute the real food of the limpet. Touching this suggestion I can only say that I have never found in any part of the alimentary tract of *Acmæa testudinalis* remains which could be interpreted as animal in nature and that I have found the animal apparently feeding upon large algæ which so far as one could see, were absolutely free from smaller organisms.

As to habits of feeding I have never been able to observe the act, but twice have, as I believe, interrupted it. In each case the seaweed to which the animal was attached bore a mark, due to the removal of the cortex, which served as a record of the

movements of the snout during feeding. The head is evidently swept slowly from side to side while the animal *backs* gradually along the surface on which it is feeding, removing the food as it goes from a band whose width is equal to the diameter of its own mouth and whose length, disposed in a series of nearly parallel but connected arcs, is proportionate to the length of the feeding time. Removal of the tissue is effected by a licking motion of the odontophore or "tongue" with its superimposed radula but I have not been able to detect any independent motion of the radula although I have made an especial search for a "chain-saw movement" such as Huxley described in certain Heteropods, and Geddes claims to have seen "in live limpets turned over on their backs," and although there are in *Acmæa fragilis* muscles which seem adapted for the production of such a motion. I have also been unable to gather any evidence as to the way in which the individual teeth of the radula are used. Pilsbry has suggested that in Rhipidoglossa the rounded form of the subradular cartilage probably determines a greater activity of the median part of the radula and that this in turn accounts for the greater specialization of the teeth in that region.

Respiration is in general aquatic and the mantle no less than the gill serves as a respiratory organ, as is demonstrated by the disposition of the blood vessels and the course of the flow. Water passes in and out beneath the slightly raised shell and its character may very possibly be tested as among some Pelecypods by the minute tentacles which fringe the mantle. The shell is usually thus raised so long as the limpet is undisturbed though the slightest disturbance causes it to be tightly pressed against the supporting rock.

Atmospheric air may, however, under certain circumstances be respired. When the water in the aquarium has become unduly warm or otherwise deprived of a part of its air, it is a common sight to see the limpets about its edges with their bodies half out of the water, the shell raised to the highest point, and the head stretched forward so that the nuchal cavity may be as widely as possible opened to the air. Such a position seems explicable only on the theory that the animals are seeking to supplement the imperfect gaseous exchange permitted by the water by a true aërial respiration.

Limpets give evidence of the possession of only three special senses: sight, touch, and the temperature sense. If they are placed in water warmer than that to which they are accustomed, they betray their uneasiness by restless wandering about. Visual sensations appear to be limited to the perception of light and darkness. That light is objectionable only when associated with heat seems indicated by the following experiment: a limpet with the pebble to which it was affixed was removed from the shaded to the sunny part of a tide pool. The water, being 12 to 15 inches deep, effectually protected it from the heat of the sun and it showed no desire to move. When the pebble was placed, however, in water only an inch or two deep and so considerably warmer, the limpet exhibited lively discomfort and crawled at once toward the shade. I have assumed that the light-perceiving organs are the eyes but have taken no steps to prove it.

The sense of touch is possessed by the entire body surface though especially localized in the tentacles, both marginal and cephalic, which are richly provided with tactile (Flemming's) cells. The gill also, although without such cells, has an exquisite sensitiveness and from its exploratory movements while the animal is traveling, would seem to serve as an additional organ of touch.

Though the sexes in *Acmæa testudinalis* are distinct, the shells show no sexual differentiation, whether in size or in form; in the ripe animal, however, the sex can usually be determined by a difference in the tint in that part of the foot which immediately underlies the generative gland. The eggs when nearly ripe assume a tint much like that known among dry-goods merchants as "crushed strawberry," and the testis at the same period is of a golden brown. On the left side of the body the gland immediately overlies the foot and is perceptible through its tissue as a patch of dull reddish or of creamy brown bounded in the median plane by a sharp line corresponding to the plane where it abuts against the green nephridium.

The breeding season appears to be a long one; I have taken ripe limpets near Boston as early as the thirteenth of April and as late as the end of July. In Eastport they were still laying

during the first week in September. In each place the generative season probably ends a little before the water reaches its maximum heat, which occurs at Eastport in September, at Boston in August. Thus all of a lot of specimens from Nahant in the middle of August had the generative glands empty and the same was true of a considerable part of those gathered at Eastport during the first few days of September. The eggs, which are about $\frac{1}{5}$ mm. in diameter are not dropped separately, as is said to be the case in Patella, but are imbedded in a layer of very thin mucus in which they lie one layer deep and at regular distances apart. The mucus is secreted not by a special gland but by the sole of the foot.

Fertilization is usually described as external. The only exception that I have been able to find to this statement is that of Fischer, who in 1863, asserted that he had found the ovaries of Patella filled with embryos already provided with the shell. Dr. Dall kindly informs me that he was following this authority when in 1879 he stated that the fertilization in Docoglossa is internal. His statement in turn seems to have been the authority for that made by Tryon in his Manual. While I am not prepared to assert that fertilization is internal I wish to record the following observation, which certainly points in that direction. About nightfall a male was observed caressing a female. Both shells were raised, that of the male overlapping the female and the heads were placed side by side, the male stroking the female with his tentacles. After a few passes he would turn as if he were going to leave her and then come back. The proceeding lasted for about half an hour, the female remaining quiescent with tentacles folded about her head. At the end of this time she moved forward, pressed the left side of the neck against the corresponding region in the male so that the openings of the two nuchal cavities were brought close together, and after remaining a moment or two in this position turned and walked away pushing with some difficulty between two other limpets neither of which paid her any other attention than a momentary touching with the tentacles. The nephridial papilla through which the generative products are extruded lies not on the left but on the right side of the nuchal cavity, but the ciliary current

is outward on that side and inward on the left so that the position which I have described would seem on the whole better fitted than the reverse one for fertilization. On the other hand, however, it should be said that when the animals were killed twenty-four hours later, the ova of the female were unfertilized and no spermatozoa were observed in her nuchal cavity or nephridium. It should also be said that in two instances unfertilized eggs have been laid in my aquaria, but as the same thing sometimes occurs with moths when pairing is prevented, no deduction can be drawn from this fact.

The eggs, at least in the aquaria, are laid about nightfall and the trochosphere is developed in the course of the next day. I have made no attempt to watch the development. Growth must be rapid, as one finds at Nahant in September and early October large numbers obviously of the season's young, which are four or five mm. in length. Sexual maturity is probably acquired after the first winter, as I have taken ripe limpets in April which were under a cm. in length.

The only enemy of the limpet of which I have had any experience is the purple, *Purpura lapillus*. I have found occasional shells bored by this mollusc and in one instance was able to surprise it in the act.

HABITS OF WEST INDIAN WHITEBAIT.

AUSTIN H. CLARK.

THE "tri-tri" or West Indian whitebait (*Sicydium plumieri*), although of small size, is one of the important food fishes of these islands. It is an inhabitant of the mountain streams, and occurs in the quiet pools and eddies formed by the back-water from rapids, from the lowlands well up into the highlands. Its range is about the same on St. Vincent as that of the "trout" (*Agonostomus monticola*), and, like that fish, it is absent from certain of the rivers.

The tri-tri reminds one strongly of the common darter (*Boleosoma nigrum olmsteadi*) in habits. They are usually observed lying motionless on the sandy bottom of pools, head up stream. They will lie in one position for a long while, then, with a sudden jerk, move to another place. If disturbed they dart quickly under the overhanging banks, or under rocks or logs in the stream. When seen on sandy bottom, the color of these fishes is a very light brownish gray, with seven or eight transverse bands of darker. If over dead leaves, or on darker masses of rock, they are a violet brown, the transverse bands being nearly black. They harmonize so well with their surroundings that they are distinguishable by a careful examination only. The adults measure from $3\frac{1}{2}$ to $4\frac{1}{2}$ inches in length. In the waters where this fish occurs there is a small slender crayfish, of the same size and color, which is very easily mistaken for it. This crustacean has the same habit of lying for a long while in one position, then suddenly moving to another, and, if disturbed takes refuge under the banks or under stones in the same way. They may usually be distinguished by the fact that they move tail first, and then occasionally crawl slowly on the bottom; they also are much commoner near the sources of the rivers, above the range of the tri-tri.

In the dry season, the adult tri-tri migrate down stream to

the sea, where they lay their eggs, probably near the mouths of the rivers from which they descended,[1] and then apparently die, as no adult fish are ever seen to return.

The young fry, when about $\frac{3}{4}$ to $1\frac{1}{4}$ inches in length ascend the rivers by thousands during the wet season (August, September, and October), moving up stream in a continuous line near or under the banks, as do the young of eels (Anguilla). When in a stretch of comparatively quiet water they move steadily onward; but in rapid water they progress by jerks, resting on the bottom for a few seconds, then making a fresh dash onward and taking a fresh grip on a pebble or rock with the ventral sucker, and, after remaining quiet for a few seconds, dashing on again. They even ascend vertical or overhanging surfaces, over which a small amount of water is running in this way, resting for a while, then moving upward an inch or so, resting again, and moving on. Sometimes during one of these ascents they are swept off and into the eddy below; but in a few minutes they are ready to try it again. I have seen as many as a dozen moving up the face of a rounded rock a foot in diameter, over which the flow of water was not enough to cover their bodies. After a heavy rain the waters of the St. Vincent rivers rise rapidly, and then fall again, leaving many little outlying pools along the banks, which, under the influence of the scorching tropical sun soon dry up, leaving dusty hollows. Many of the fishes become cut off from the main stream at such times, and, as the pools dry up may be seen jumping about in the hollows, entirely covered with a thick coating of dust. If these stranded individuals be placed again in the main stream, they soon begin to ascend with the others as if nothing had happened. The tenacity of life of the young tri-tri is remarkable. They will live for several hours in these dry situations, exposed to the full rays of the sun.

The journey of the fry up the rivers occurs at the time when

[1] The fact that certain rivers in these islands, apparently suitable in every way for these fish are not inhabited by them seems to point toward the fact that the fish from the neighboring streams spawn in the vicinity of their mouths; otherwise we should expect to find a few of the young straying into these uninhabited streams every year.

the migratory shore birds from the north are making their brief stay in these islands, and certain species appear to feed largely on these fishes. On the Richmond River in St. Vincent, where, on account of the lack of vegetation, consequent on the late eruptions of the Soufrière, birds may be readily observed, I found the following species feeding on the young tri-tri. Near the mouth were blue herons (*Florida cærulea cærulescens*), golden plover (*Charadrius dominicus*), turnstones (*Arenaria interpres*), willet (*Symphemia semipalmata*), greater yellow-legs (*Totanus melanoleucus*), lesser yellow-legs (*T. flavipes*), solitary sandpipers (*Helodromas solitarius*), spotted sandpipers (*Actitis macularia*), green herons (*Butorides virescens maculata*), and kingfishers (*Ceryle alcyon*). The solitary sandpipers followed the fish up into the lowlands at the base of the hills, the green herons and kingfishers to the edge of, and even just within the forests, while the spotted sandpipers are found well up into the mountains. About the mouth of the river I also observed white herons (*Garzetta candidissima*), great blue herons (*Ardea herodias*), and fish hawks (*Pandion haliaëtus carolinensis*), probably attracted by the larger fish which were following the young tri-tri in from the sea, and which were abundant about the river's mouth.

On reaching the pools at the higher altitudes the fish select some suitable spot and there remain until maturity, when they return to the sea to deposit their eggs. I was unable to ascertain just how long this period was.

During their ascent of the streams, numbers of the young are caught by the natives and eaten, either boiled (whole) or fried into cakes. Although when cooked they bear a strong resemblance to maggots, they are very good, tasting something like whitebait.

These fish, or a closely allied species, are abundant in certain streams in Grenada, but are not found on the Grenadines. Their local name is a corruption of that given them by the original Caribs.

NOTES AND LITERATURE.

ZOÖLOGY.

Fishes and Ascidians. — The seventh volume of the now well established Cambridge Natural History[1] contains accounts of the fishes, ascidians, etc., and brings the series to within three of completion. This volume opens with a discussion of the Hemichordata by S. F. Harmer. Dr. Harmer's readable account of these very interesting animals presents a concise description of the habits, distribution, and anatomy of such forms as Balanoglossus, Cephalodiscus, and Phoronis; and concludes with a judicious summary of the evidence as to their affinities. Dr. Herdman contributes the article on the ascidians and amphioxus. This opens with a description of the anatomy of a typical ascidian, after which a general systematic consideration of the group is given. The chapter on amphioxus deals in a brief way with the habits, structure, and embryology of this important form. Here and there revised statements would have improved the text, as for instance those on the condition of the eye spots which were so admirably portrayed recently by Hesse. The commendable feature of illustrating geographical distribution by a chart is here marred by the fact that the signs used to represent Branchiostoma and Asymmetron are not printed with sufficient clearness to make them always unquestionable.

By far the larger part of the volume is given to the fishes, the general account of which comes from Dr. T. W. Bridge and the systematic part on the teleosts from Dr. Boulenger. Dr. Bridge's contribution is a safely conservative body of statement on the anatomy of fishes with a reasonable amount of natural history included in the systematic consideration of all groups except the teleosts. The account in the main is excellent but is marred here and there by insufficiency. Thus in dealing with the ear the author treats the organ as an unquestionable organ of hearing, omitting all mention of its equilibration function, the only function thus far known for it in such forms as the dogfish. Both Dr. Bridge's and Dr. Boulenger's

[1] *The Cambridge Natural History*. Vol. VII. Edited by S. F. Harmer and A. E. Shipley. Macmillan Co., New York, 1904. 8vo, xviii + 760 pp., 440 figs.

portions of the systematic account of the fishes are admirably illustrated and the accompanying charts of geographical distribution of families, etc., add much to the lucidity of the presentation. This volume is undoubtedly bound to rank high among its predecessors in this excellent series.

G. H. P.

Essays on Transformism. — Professor A. Giard [1] has collected and published in book form seven of his essays which appeared during the last twenty-five years and which all deal with evolutionary matters. The essays, which are in no essential respects changed from their original form, deal with the history of transformism, the embryology of ascidians and the origin of vertebrates, biology and taxonomy, the factors of evolution, Lamarck's principle and the heredity of somatic variations, convergence in pelagic forms, and animal symmetry; and afford a convenient collection for those interested in the evolutionary speculations of this well known French biologist.

G. H. P.

Morphology and Anthropology.[2] — The growth of anthropology particularly in its relations to morphology is well exemplified in the last number of the Cambridge Biological Series by Duckworth. The object of the volume is to set before the student a concise exposition of man's place in Nature as determined by natural history methods. The first part of the book deals with this question from the standpoint of comparative anatomy and describes in an abbreviated way the systems of organs in the mammals and especially in the primates, devoting particular attention to the crania and teeth. Then follows a condensed account of human embryology, after which anatomical variations are taken up. These fill the greater part of the volume, the last section of which deals with palæontological materials of importance to anthropology. The condensation of so much substance into so small a space often seriously interferes with an adequate treatment of the subject and one is often led to suspect that the volume may be found more acceptable to the student who is cramming for an examination than to the one who is seriously engaged in a real study of anthropology; nor does the preface sug-

[1] Giard, A. *Controverses Transformistes.* C. Naud, Paris. 8vo, viii + 180 pp., 23 figs.

[2] Duckworth, W. L. H. *Morphology and Anthropology.* Cambridge Biological Series, Macmillan & Co., 1904. 8vo, xxviii + 564 pp., 333 figs., 5 charts.

gest that this use of the book was far from the author's intentions. However commendable such a standpoint may be, it is almost invariably assumed to the detriment of the really serious study of the subject. As an examination compendium the volume has much to recommend it; but as a contribution to the science of anthropology it is much less satisfactory. The illustrations are numerous but often crude and harsh.

G. H. P.

Northern Plankton.[1]—The Hensen school of planktologists at Kiel have undertaken, under the leadership of Professor Karl Brandt, to issue a monograph of all the organisms found in the plankton of northern seas above 50° N. Associated with the editor-in-chief in this undertaking are twenty specialists, each an authority on the group of organisms with which he deals.

The literature which pertains to the complex of organisms composing the plankton is widely scattered and much of it inaccessible except in the large libraries at the great centers of learning. A comprehensive manual of the plankton will therefore be most welcome, not only to the biologist at the seashore who wishes to acquaint him self quickly with pelagic organisms, but also to the beginner who for the first time beholds the marvels of the "tow." The usefulness of this work is enhanced by the fact that nearly every species is represented by a "Habitusbild" or detail figure of diagnostic characters. Although limited in its scope to the fauna of northern and arctic seas, and based largely upon the investigations along the coasts of northern Europe, it is not a work of merely local interest, useful only within the limits of latitude which the editors have chosen, for the organisms of the plankton are in many cases cosmopolitan in their distribution and many species of the warm temperate Atlantic are carried by the Gulf Stream far beyond 50° N.

The work is to consist of twenty-one sections numbered in zoölogical and botanical sequence, each with independent pagination, and issued in parts as rapidly as the papers are prepared. Part I contains five of these sections, the pelagic tunicates by Drs. Borgert, Apstein, and Lohmann; the Ostracoda by Professor G. W. Müller

[1] Brandt, K. *Nordisches Plankton.* Lipsius & Tischer, Kiel and Leipzig, 1903. Erste Lieferung. Sect. III, 21 pp., 24 figs.; VII, 15 pp., 24 figs.; IX, 30 pp., 34 figs.; XIV, 32 pp., 33 figs.; XV, 52 pp., 56 figs. 1901. M. 6.—Zweite Lieferung. Sect. XI, 7 pp., 16 figs.; XX, 29 pp., 25 figs.; XXI, 40 pp., 135 figs. M. 3.60.

and the Cladocera by Dr. Apstein; the echinoderm larvæ by Dr. Th. Mortensen; the Foraminifera by Professor Rhumbler; and the Tripylea (= Phæodaria Hkl.) by Dr. Borgert. Part II contains the Ctenophora by Dr. Vanhöffen; the Schizophyceæ by Prof. N. Wille; and the Flagellatæ, Chlorophyceæ. Coccosphærales, and Silicoflagellatæ by Dr. E. Lemmermann.

As usual in works of composite authorship we find here considerable variety in the method and form of treatment, especially in matters of literature and synonymy. The admission of a large number of fresh-water species in the sections dealing with the Schizophyceæ, Chlorophyceæ, and Flagellatæ seems ill advised. They occur in brackish waters only and are generally adventitious even there, and have no part in the marine plankton. The authors of the sections dealing with the Ostracoda and Cladocera have excluded all adventitious forms from fresh water. It is to be hoped that the appearance of the remaining parts of this most useful manual may not be long delayed.

C. A. K.

Wild Birds and their Music.[1]— Notwithstanding the present-day abundance of popular guides to the study of our native birds, Mr. Mathews has found an almost untouched field in preparing a guide to the songs of the commoner species of the eastern United States. In this artistic little volume of 262 pages, the songs and characteristic notes of 82 species are carefully analyzed and set down in musical notation or in line and dot diagrams, and these are so explained as to be quite intelligible, even to one who has no technical knowledge of music. To the beginner in bird study, who finds it much easier to hear birds than to see them, this book cannot fail to be an aid in identifying the commoner song-birds. In addition to the musical description, a brief diagnosis of each species is added, together with a statement of its distribution. A number of plates in wash or in color illustrate nearly all the birds described in the text. All these are from drawings by the author, and although many of them are admirable, others have evidently suffered much in the reproduction. A good index enhances the value of this book for field use.

G. M. A.

[1] Mathews, F. Schuyler. *Field Book of Wild Birds and their Music.* New York; G. P. Putnam's Sons, 1904. 16mo, xxxv + 262 pp., illus. $2.00.

BOTANY.

New England Ferns and their Allies.[1]— This attractive little volume is intended as a popular guide to the New England ferns, club-mosses, and horse-tails. In a preliminary chapter, the various species are grouped first by their fruiting seasons, and then by the nature of their habitats. Each species is then described briefly and the more evident characteristics of closely allied forms are contrasted. Brief remarks follow on the general distribution, habit, and manner of fruiting. The descriptions are supplemented by one or more excellent illustrations of each species from photographs of fresh specimens. A key to the genera of the ferns treated, a glossary, and an index conclude this handbook. It is substantially bound and of a convenient size, and cannot fail to be of service to the increasing class of out-of-door folk who wish to know the names of the plants met with in their summer excursions.

G. M. A.

[1] Eastman, Helen. *New England Ferns and their Common Allies, an easy Method of determining the Species.* Boston and New York: Houghton, Mifflin and Co., 1904. 12mo, xxi + 161 pp., illus.

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FOSSIL GRASSES AND SEDGES.[1]

EDWARD W. BERRY.

In number of species the Glumales (Graminales, Poales) is one of the greatest angiospermous alliances. Aside from the forms known as weeds or the cultivated species which have been generally distributed by commerce and colonization, the group is cosmopolitan, with common species in the northern and southern as well as the eastern and western hemispheres. The distribution is very uniform, no one tribe or large genus being confined to a single geographic area, abundant proof in itself that the Glumales are an old type, whose generic evolution occurred far back in geological history.

The known geological record does not, however, throw much light on this subject. From the nature of the case the most we can expect of fossil grasses and sedges is that they will give us some idea when these types first appeared on the globe and when they became abundant and widespread. We cannot expect to unravel the botanical affinities of stray bits of leaf or indefinite remains of inflorescence (Panicum), culms (Culmites), or rhizomes (Rhizocaulon) in plants whose leaf-form and general struc-

[1] Published by permission of the Maryland Geological Survey.

ture is so uniform; nor can the names bestowed upon these remains be taken to indicate relationship with the modern forms except in a most generalized sense, indicating rather the personal preference or convenience of their describers. However, as organic remains of frequent occurrence and definite character they deserve a place in fossil floras, and are perhaps more useful to the geologist than to the botanist.

Summarizing the described species, we may note that we have no evidence of grasses nor of sedges during the Paleozoic. When parallel-veined leaves were supposed to indicate exclusively Monocotyledonous character a number of supposed forms were described from the Carboniferous. These have since been found to be Calamarian or Sigillarian leaves. The remains from the older Mesozoic show little improvement in definiteness. We would expect grasses to have existed, and in fact a score of species have been described from the Jurassic (Poacites, Bambusium, etc.). Saporta in particular has described numerous species of grass-like or sedge-like leaves under the name Poacites.[1]

The Cretaceous seems to have been very poorly provided with sedges, if we may judge from the fossils, chiefly described under the name Cyperacites; the grasses, however, are quite numerous during this period (Arundo, Phragmites, Culmites, Poacites, etc.). With the ushering in of the Tertiary, both grasses and sedges become more common, upward of two score species of each type having been described from the Eocene. It is in the Miocene, however, that the greatest display of fossil grasses and sedges is made, there being numerous species founded on culms, glumes, inflorescence, rhizomes, and leaves (Carex, Cyperus, Cyperites, Cyperacites, Oryza, Panicum, Arundo, Arundinites, Phragmites, Bambusa, Uniola, Palæo-Avena, etc.).

Referring more specifically to the Cyperaceæ, it may be noted that the middle and lower Cretaceous of this country, which include the abundant, plant-bearing Potomac beds (Fontaine), the Dakota group (Lesquereux), and the Raritan (Newberry,

[1] As a matter of fact, Poacites as characterized by Brongniart in 1822 was monotypic, and his species having been relegated to synonymy, the name is not available for the Mesozoic species.

Hollick) do not show any recognizable remains of sedges. Dawson has described one doubtful form from the lower Cretaceous (Urgonian) of British Columbia, and Heer has described two species founded on rather more definite remains of leaves from the Kome beds (Urgonian) of Greenland. This paucity of remains renders the discovery of the following species of some importance, as it was evidently abundant in the Atlantic coastal plain at a time when those transition beds between the typical Raritan and the typical Matawan were being laid down.

Carex clarkii sp. nov. (Fig. 1.)

Remains consist of fragments of leaves up to 6 cm. in length, and varying in width from 1.5 to 4 mm., averaging between 2

Fig. 1.— Specimen of *Carex clarkii* from Grove Point, Maryland.

and 3 mm. in the specimens collected. Leaves slightly keeled, evidently becoming somewhat thicker and narrower toward the base. Midrib moderately prominent, lateral veins very fine and scarcely discernible, except in the larger specimens.

The type material was collected originally by Dr. Wm. Bullock Clark at Grove Point, Maryland. Similar material has been collected in a different leaf-bed on Grove Point by Bibbins and Berry, who also collected it in less abundance at the Deep Cut of the Chesapeake and Delaware Canal in Delaware. In overhauling my collections from Cliffwood, N. J., I found three small fragments, hitherto undescribed, which are identical with the specimens from further south. I now have twenty-two specimens of this form from the Grove Point locality, five from Deep Cut, and three from Cliffwood. Five specimens were recently collected by the writer from the west bank of Cheesequake Creek one-half mile southwest from Morgan Station.

It has seemed best not to press the comparison with other species from widely different geological horizons too closely. Our species might readily enough be correlated with almost any of the thirty-nine species of Cyperaceæ which Heer describes from the Miocene of Switzerland, and the resemblance is also very close to some of the leaves which Saporta refers to Poacites (*e. g.*, *P. antiquior*, *tenellus*, *cerealinus*). So much confusion results from identifying as common, forms widely separated, either geologically or geographically, when the determinations are based upon any but the most complete material, that it has seemed best to describe the American remains as a new species, as I have no doubt it really is.

PASSAIC, N. J.

CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE. E. L. MARK, DIRECTOR. No. 165.

POSTERIOR CONNECTIONS OF THE LATERAL VEIN OF THE SKATE.

HERBERT W. RAND AND JOHN L. ULRICH.

For several years the senior author has used the skate to illustrate to classes in the comparative anatomy of vertebrates the main features of the primitive circulatory system of vertebrates. The injection of the systemic veins of the skate is attended with more or less difficulty, especially at the hands of students of little experience, and even under the most favorable circumstances it is difficult, if not impossible, to secure a complete injection of the veins by the methods ordinarily prescribed (see, for example, T. J. Parker, '95, pp. 48–49). The difficulty lies partly in the fact that the veins are well provided with valves, which impede the flow of the injection mass in a direction the reverse of that of the blood-flow, and partly in the presence of large thin-walled sinuses which are likely to rupture before the injection mass can be forced into the smaller vessels and those more remote from the point of injection. Although a large number of injected skates had come under observation in the laboratory, the relations of certain of the veins in the region of the kidneys had never been clearly demonstrated.

The veins of certain foreign species of skate have been well described, notably by T. J. Parker ('81). Conditions similar to those found in foreign skates are to be expected in our local species. Nevertheless, it seemed to the authors to be worth while to determine precisely the condition of the vessels whose connections were in doubt, especially in view of the fact that there was strong evidence of one striking difference between our common skate and the species described by Parker, in the pos-

terior connections of the lateral veins. The importance of a complete knowledge of the details of skate anatomy is increased by the fact that the skate is, in some respects, so peculiarly adapted for use in the laboratory work of classes in comparative anatomy. In another paper (Rand, :05) attention has been called to the advantages of the skate for this purpose, where also methods of injecting the blood vessels are discussed.

The first complete description of the connections of the lateral vein of the skate is that given by T. J. Parker in his paper "On the Venous System of the Skate (*Raja nasuta*)" in 1881. Previous to Parker's description these veins had been imperfectly described by several anatomists. Monro ('85) observed the lateral veins in skates, but did not determine their posterior extent and connections. Robin ('45) gave an incomplete and not very clear account of the lateral veins of *Raia clavata* L., *R. rubus* L., and *R. batis* L., but at first regarded them as lymphatic vessels. He described the two lateral vessels as inosculating at their posterior ends. He afterwards recognized the true nature of the vessels.

Parker ('81) gave a complete and clear account of the chief veins of *Raia nasuta*. Figure 1 is a diagram showing the connections of the important vessels as represented in the figure accompanying Parker's paper. A similar figure is given in his *Zootomy* ('95, p. 53). According to Parker's account, the lateral vein (*vn. l.*), having received the several brachial veins, opens anteriorly into the precaval sinus. Throughout its extent along the lateral wall of the abdominal cavity, the lateral vessel receives veins from the abdominal walls. The nomenclature used above is not that of the paper cited, but corresponds to that of Parker's later paper ('86) on the blood vessels of *Mustelus antarcticus*. Posteriorly it receives the femoral vein and just back of that point becomes continuous with a large trunk which "passes dorsalwards, ... curving along the posterior wall of the pelvic cavity, then passing on to the lateral wall of the cloaca, along which it takes its course as far as to the rectal gland, where, with its fellow of the opposite side, it enters a hinder prolongation of the cardinal sinus, first receiving numerous small veins from the cloaca and rectum" (Parker, '81, pp. 415–416).

"These latter, I have no doubt," says Parker, "although I have not actually proved it, anastomose with factors of the portal vein" (p. 416). The large trunk which constitutes a direct continuation of the lateral vein from its femoral region into the cardinal sinus was called by Parker the *ilio-hæmorrhoidal vein* because it "seems to correspond in all essential respects to the iliac vein" and "also receives the hæmorrhoidal veins from the rectum and cloaca" (p. 416). The arrangement described by Parker is virtually that of a continuous large venous trunk open-

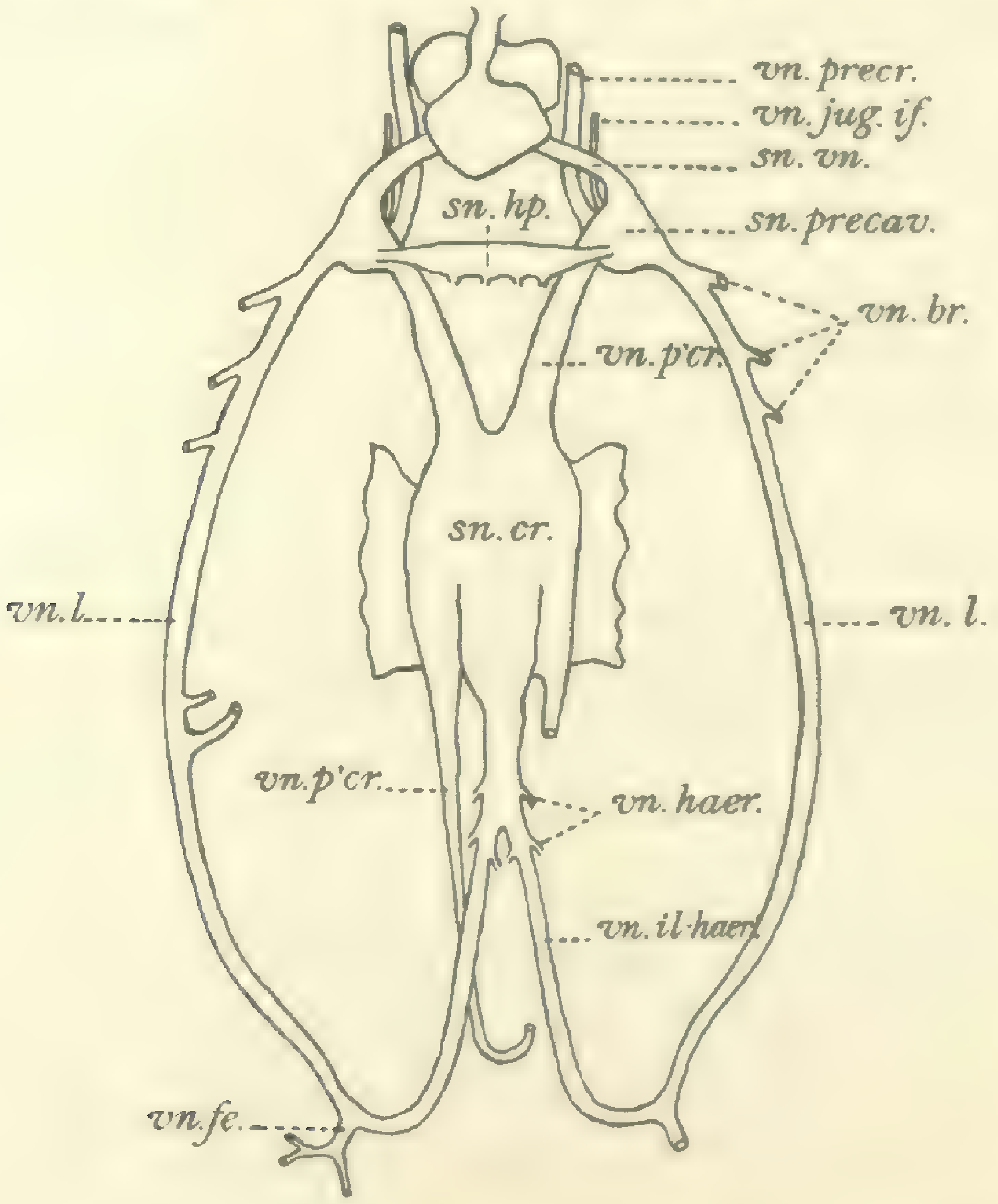

FIG. 1.—Venous system of *Raia nasuta*. After T. J. Parker. *sn. cr.*, cardinal sinus; *sn. hp.*, hepatic sinus; *sn. precav.*, precaval sinus; *sn. vn.*, venous sinus; *vn. br.*, brachial veins; *vn. fe.*, femoral vein; *vn. hær.*, hæmorrhoidal veins; *vn. il-hær.*, ilio-hæmorrhoidal veins; *vn. jug. if.*, inferior jugular vein; *vn. l.*, lateral vein; *vn. p'cr.*, postcardinal vein; *vn. precr.*, precardinal vein.

ing at its anterior end into the precaval sinus and at its posterior end into a posterior extension of the cardinal sinus, its chief tributaries being the brachial and femoral veins and veins from the abdominal wall.

Jourdain ('59) in his "Recherches sur la Veine Porte Rénale," does not mention the lateral veins, but describes the femoral

veins in *Raia clavata* L. as opening each into the corresponding renal portal vein.

Hochstetter ('88) gives the following account of the lateral veins of *Spinax* [= *Squalus*] *acanthias*: "Neben den Venæ subclaviæ münden caudalwärts von ihnen jederseits eine Vene, in die Cardinalvenen, die Seitenvene. . . . . Diese beiden Gefässe wurzeln in einem Venennetze, welches die Kloake umspinnt und mit den Pfortaderzweigen des Enddarmes anastomosirt. Aus diesem Netze gehen rechts und links die beiden Venen hervor, welche angeschlossen an die dorsale Fläche des Beckenknorpels zunächst die Vene der hinteren Extremität aufnehmen und hierauf umbiegend, geradeaus kopfwärts verlaufen und auf diesem Wege die Venen der Bauchmuskeln aufnehmen" (p. 126). In the rays, Hochstetter says, the lateral veins exhibit substantially the same condition as that described for Squalus.

We were led to investigate the posterior connections of the lateral vein of the skate owing to the fact that, in the numerous animals which had come under observation in the laboratory, there had never been seen the least evidence of the "ilio-hæmorrhoidal" trunks described by Parker for *Raia nasuta*. In a freshly-killed skate (*R. erinacea* or *R. lævis*, Fig. 4) the lateral veins, lying just beneath the peritoneum, are conspicuous vessels because of the blood contained in them. They may be followed back to the pelvic region, where they disappear from view. The cardinal sinus is usually well filled with blood and a posterior extension of this sinus may be traced back to the base of the rectal gland. This extension evidently corresponds to the "hinder prolongation of the cardinal sinus" described by Parker as receiving the ilio-hæmorrhoidal veins, but no large trunks are to be seen opening into it. Attempts to trace the uninjected vessels by dissection resulted negatively, so far as any connection between the hind end of the lateral vein and the cardinal sinus is concerned, although a connection of the lateral vein with a vein from the pelvic fin was found. Furthermore, observation of a large number of injected skates had given no evidence of the existence of "ilio-hæmorrhoidal" veins. These injections, however, being of raw starch or of plaster of Paris, were not calculated to show a connection between lateral vein

and cardinal sinus by means of minute vessels, if such existed. Accordingly we undertook to determine if any connection whatever was to be demonstrated.

Six fresh skates were secured, four of them being the common *Raia erinacea* and two *R. lævis*. Our operations and results upon these six animals are described below. In each case the caudal vein was injected for the purpose of differentiating the renal portal connections. The celloidin injections were made with very thin, easily flowing celloidin colored with finely pulverized carmine or Prussian blue. Careful dissections and drawings of the injected vessels were made by Mr. Ulrich.

I. Raia lævis: young male.

1. Renal portal system injected, *via* the caudal vein, with blue celloidin.

Minute separated masses of the celloidin appeared in the postcardinal veins, apparently having passed through the renal capillaries. A considerable quantity of celloidin from this source collected in the cardinal sinus and some of it made its way back into the posterior or rectal prolongation of that sinus.

2. Left lateral vein injected posteriorly with red celloidin.

The red mass appeared on the walls of the cloaca and rectum in a close network of very fine vessels extending forward to, and a little beyond, the base of the rectal gland. Small vessels connected with this network conveyed the celloidin along the ventral margin of the mesorectum, in the region of its attachment to the rectum, apparently into the posterior end of the rectal prolongation of the cardinal sinus. Here an interval of only three or four millimeters separated the blue and red injection masses.

The dissection of this fish proved that both the red and the blue celloidin had entered the rectal prolongation of the cardinal sinus. The failure of the two masses actually to meet was doubtless caused by the inclusion between them of a quantity of gas for which there was no avenue of escape. The lateral vein received two trunks from the pelvic fin. The larger one of the two emerged from the fin dorsal to the end of the girdle and

just posterior to the iliac process. The smaller vein left the fin on the anterior side of the first or pre-axial fin-ray.

II. Raia erinacea: young male.

1. Renal portal system injected, *via* the caudal vein, with blue celloidin.

A small amount of the celloidin appeared in the cardinal sinus.

2. Left lateral vein injected posteriorly with red celloidin.

The mass did not appear on the rectum.

During the progress of the injection the posterior margin of the left pelvic fin was cut away. The red celloidin escaped from a small vessel lying along the median edge of the clasper.

In the dissection of this fish the lateral vein was traced to the wall of the cloaca, where it was lost in fine branches. A large vein from the pelvic fin was found opening into the lateral vein at a point dorsal to the girdle and just posterior to its iliac process.

III. Raia erinacea: female.

1. Renal portal system injected, *via* the caudal vein, with blue (raw) starch.

The starch mass did not pass into the cardinal sinus.

2. Left lateral vein injected posteriorly with red celloidin.

A fine anastomosing network on the cloaca and rectum was injected, as in I.

The left pelvic fin was cut, as in II. There was slight evidence of the red celloidin at the cut surface.

By dissection, the lateral vein was traced back along the pelvic region of the abdominal wall and onto the lateral wall of the cloaca along which it ran, giving off numerous branches and rapidly diminishing in caliber, to a point about 15 millimeters posterior to the rectal gland, where it became completely lost in a fine network.

The lateral vein was found to receive from the pelvic fin a fairly large trunk which emerged from the fin on the anterior side of the first or pre-axial fin-ray.

IV. Raia erinacea: large male.

1. Blue starch injected into the caudal vein.

The blue starch appeared in the left lateral vein and filled the greater portion of it, together with some of its branches from the body wall.

Dissection of the animal showed that the renal portal system was fully injected. The position and connections of the vein which put into direct communication the renal portal and lateral systems are represented in Figure 2. Lying transversely on the left dorsal body wall was found a large vein (Fig. 2, *x*) opening at

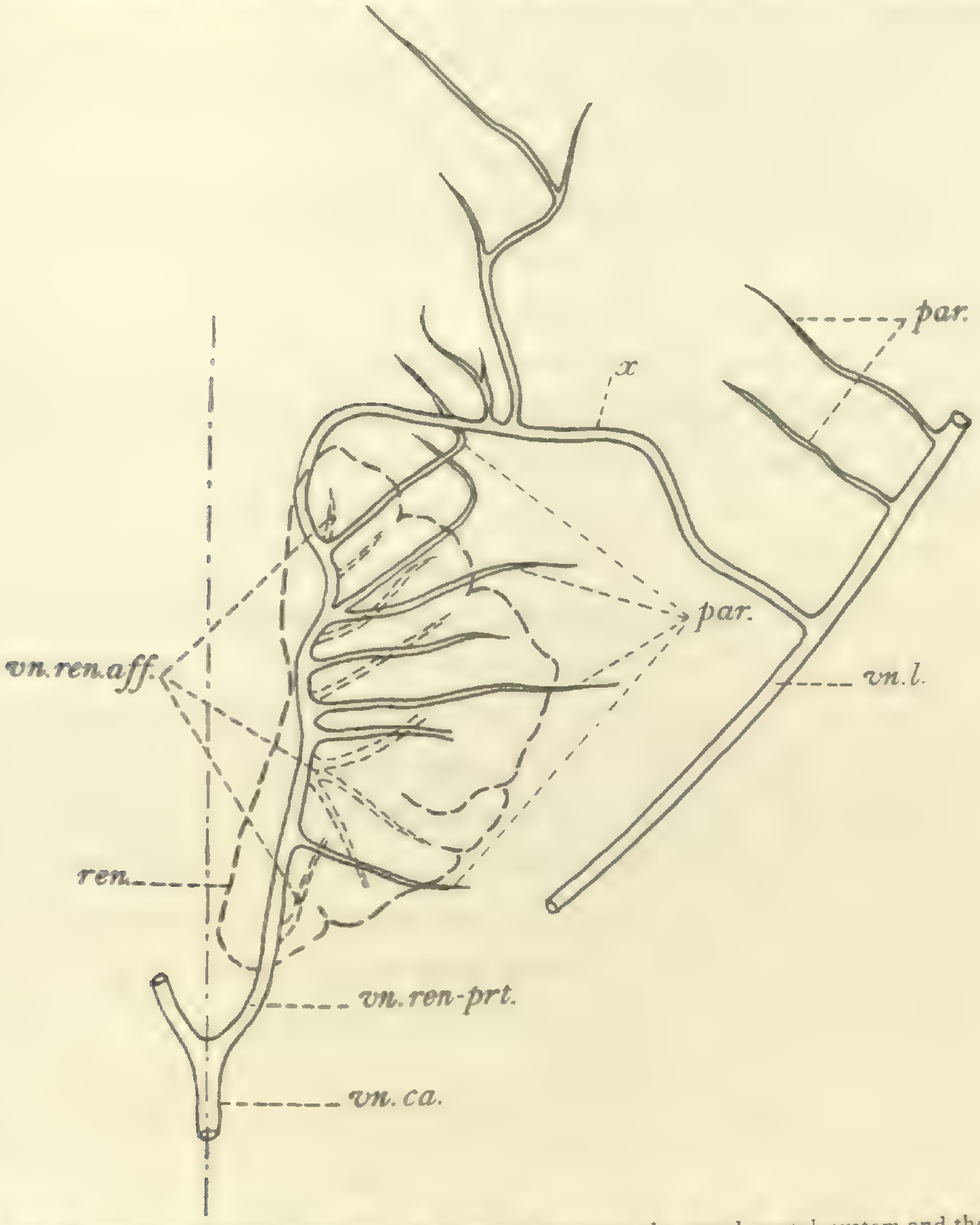

FIG. 2.— Showing the connection found in Case IV between the renal portal system and the lateral vein. *par.*, parietal branches of the renal portal and lateral veins; *ren.*, kidney; *vn. ca.*, caudal vein; *vn. l.*, lateral vein; *vn. ren. aff.*, afferent renal veins; *vn. ren-prt.*, renal portal vein; *x*, vein connecting renal portal and lateral veins.

its one end into the left lateral vein, and at its other into a large anterior renal portal component, which was virtually a direct continuation of the renal portal vein itself forward on the dorsal body wall. Jourdain ('59) describes a similar anterior component of the renal portal system.

The extreme posterior end of the lateral vein was found to be not injected.

V. Raia lævis: very large female.

1. Renal portal system injected, *via* the caudal vein, with blue starch.

2. Left lateral vein injected posteriorly with red celloidin.

A particularly full injection of the branches of the posterior part of the lateral vein was secured. The mass appeared on the walls of the cloaca and rectum in an anastomosing network of fine vessels, which were traceable along the rectum to a region about one centimeter anterior to the duct of the rectal gland. The mass was seen also in small vessels on the ventral margin of the mesorectum, and *a considerable quantity of it passed through the rectal extension of the cardinal sinus into the main part of that sinus.*

The left pelvic fin was cut, as in preceding cases, and the red mass escaped from small vessels along its median edge.

The dissection of this animal demonstrated clearly a connection between the venous network on the rectum and the cardinal sinus. The lateral vein was traced forward a short distance on the side of the rectum and there broke up into fine branches which anastomosed with vessels of the network. Along the margin of the mesorectum, in the region of the base of the rectal gland, several small vessels resolved themselves out of the network and communicated with the posterior end of the rectal extension of the cardinal sinus.

From the pelvic fin the lateral vein received two large trunks and one very small vein (see Fig. 4). The largest trunk emerged from the fin just posterior to the iliac process of the girdle, corresponding, therefore, with the one vein found in II and with the posterior one of the two veins found in I. This

trunk, from its position and size, is doubtless entitled to the name, *femoral vein.* It receives one large branch from the median side of the basipterygium. The remainder of its branches are distributed upon the external side of the basipterygium, collecting the blood from much the greater portion of the fin. A second and considerably smaller vein emerged from the fin on the anterior side of the pre-axial fin-ray, corresponding with the vein found in III and with the anterior one of the two veins found in I. The branches of this vein were distributed around the large pre-axial fin-ray, the main axis of the vein lying along the anterior side of the ray.

The third one of the three veins mentioned as entering the lateral vein from the pelvic fin was a very small vessel which lay just anterior to the iliac process of the girdle.

VI. Raia erinacea: small female.

1. Renal portal system injected, *via* the caudal vein, with blue celloidin.

A trace of the celloidin appeared in the right postcardinal vein.

2. Right lateral vein injected posteriorly with red celloidin.

The mass entered a fine network of vessels on the cloaca and rectum, passed through minute vessels lying along the ventral margin of the mesorectum, and a small quantity of it collected in the rectal extension of the cardinal sinus.

By dissection, the lateral vein was traced up to the wall of the cloaca (see Fig. 3), where, at a point nearly in the same transverse plane with the anterior end of the external cloacal aperture, it divided into two branches. Each of these immediately broke up into fine branches which anastomosed with vessels of the network. On the dorsal wall of the rectum and just behind the rectal gland, the network resolved itself into a system of fine vessels (Fig. 3, A and B, *vn.*) lying nearly parallel with one another, frequently anastomosing, and converging forward into fewer and larger vessels in such a way that there was a gradual transition from the rectal network into the single very narrow lumen of the posterior tip of the cardinal sinus.

No veins from the pelvic fin were injected.

Examination of a number of skates which had been injected (by students) with starch or a starch-gelatin mixture (see Rand, :05) brought to light several animals in which the rectal venous network had been more or less completely filled from the cardinal sinus. In these cases, the lateral vein had been injected forward, but not backward. The cardinal sinus had

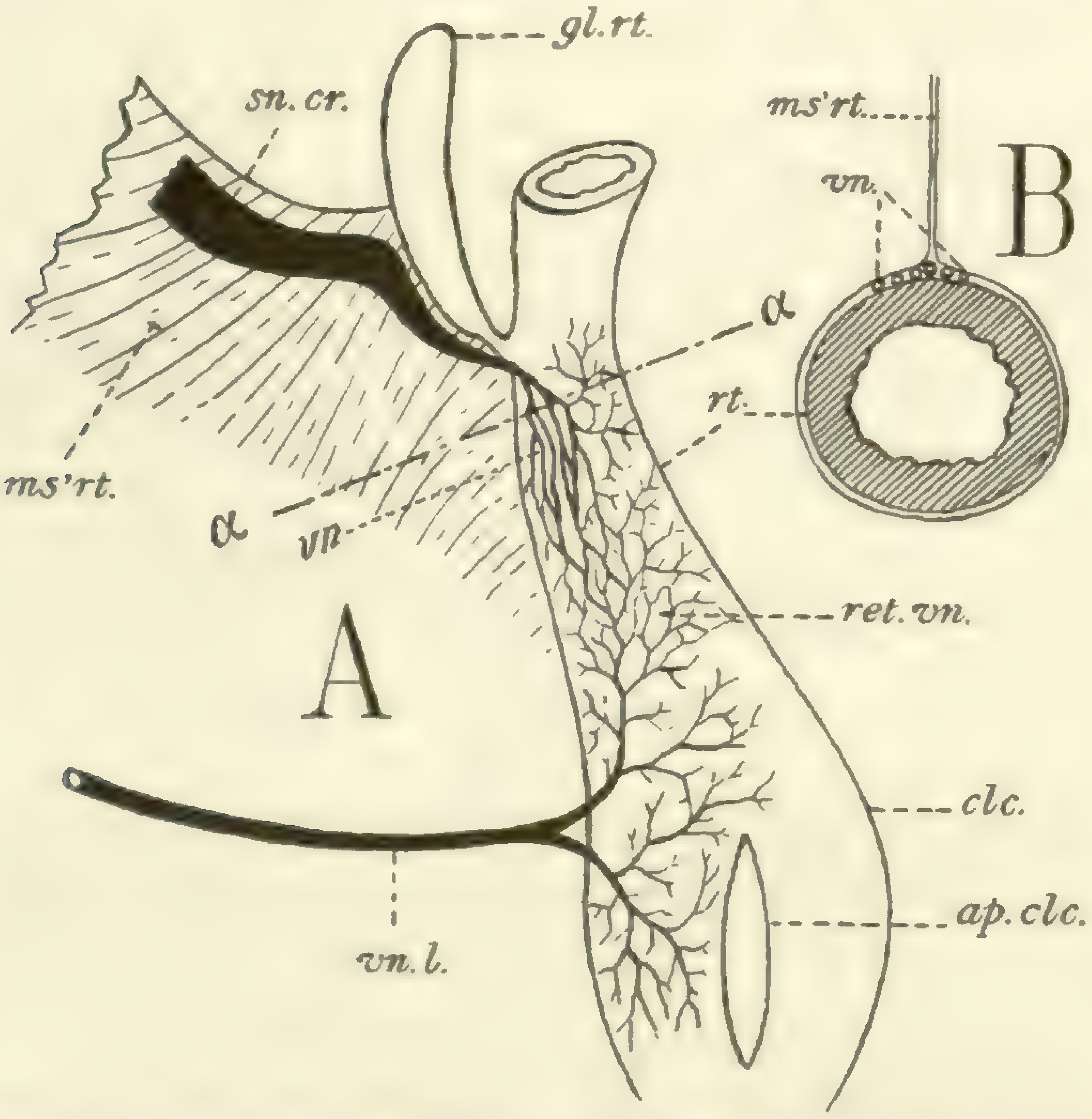

Fig. 3.—Showing the relation found in Case VI between the posterior end of the lateral vein and the cardinal sinus.

A. The cloacal region is seen from the ventral aspect, but the rectum is twisted through 90° so as to bring into view the right side of its anterior region as well as the right side of the rectal gland and mesorectum.

B. Cross section (enlarged) of the rectum at **α–α**.

ap. clc., cloacal aperture; *clc.*, cloaca; *gl.rt.*, rectal gland; *ms'rt.*, mesorectum; *ret. vn.*, venous network on cloaca and rectum; *rt.*, rectum; *sn. cr.*, rectal prolongation of cardinal sinus; *vn.*, veins connecting rectal venous network with cardinal sinus; *vn. l.*, lateral vein.

filled from the precaval (Cuvierian) sinus and the mass had made its way back through the rectal extension of the cardinal sinus into the rectal network. This network, therefore, may be injected either from behind, by way of the lateral vein, or from before, by way of the cardinal sinus. Figure 4 shows the lateral vein in its entire extent, with its connections as found in our injected skates.

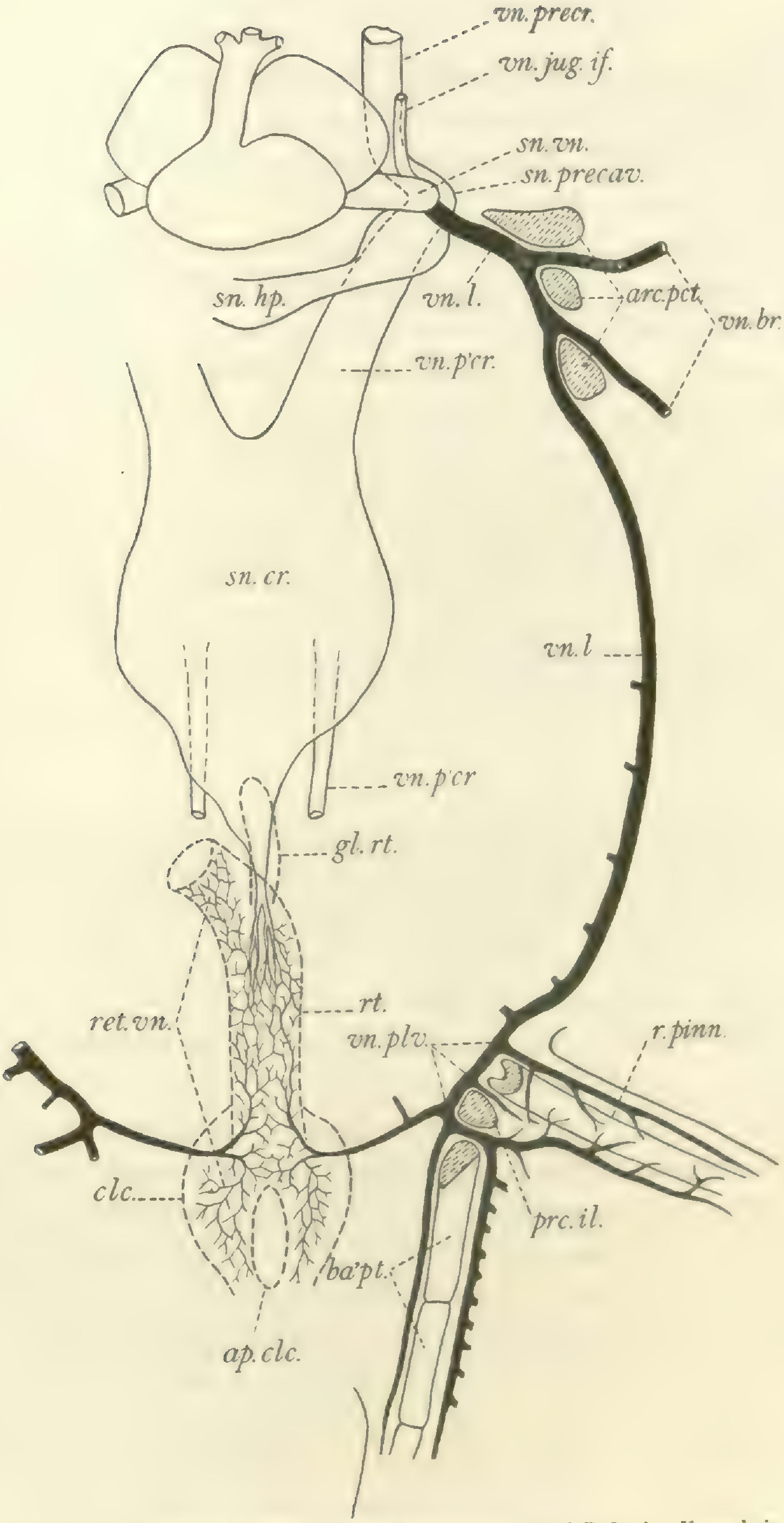

FIG. 4.—The lateral vein and its connections in *Raia erinacea* and *R. lævis*. Ventral view. *arc. pct.*, pectoral girdle; *ap. clc.*, cloacal aperture: *ba'pt.*, basipterygium; *clc.*, cloaca; *gl. rt.*, rectal gland; *prc. il.*, iliac process of pelvic girdle; *r. pinn.*, pre-axial ray of pelvic fin; *ret. vn.*, venous network on cloaca and rectum; *rt.*, rectum; *sn. cr.*, cardinal sinus; *sn. hp.*, hepatic sinus; *sn. precav.*, precaval sinus; *sn. vn.*, venous sinus; *vn. br.*, brachial veins; *vn. jug. if.*, inferior jugular vein; *vn. l.*, lateral vein; *vn. p'cr.*, postcardinal vein; *vn. plv.*, veins from pelvic fin; *vn. precr.*, precardinal vein.

Do the veins of the rectal network communicate directly with the posterior factors of the hepatic portal system, as stated by Hochstetter for Squalus, and as thought probable by Parker ('81) for *Raia nasuta*?

Good starch injections of the intestinal veins often result in the demonstration of a venous network on the rectum in the region of the base of the rectal gland. The network which has been demonstrated by injection from the lateral vein often extends into the same region. It is improbable that there should be two distinct and non-communicating sets of veins in this same region of the intestine. In one case (I) the red celloidin passed through the venous network on the rectum and appeared in a very small vessel which was identified, with a fair degree of certainty, as the extreme posterior end of the mesenteric or dorsal intestinal vein, the hindmost trunk of the hepatic portal system. The failure of the celloidin to flow freely through the network into the hepatic portal vessels, granting that the connection exists, might well be due to the solidifying of the celloidin in the fine vessels of the network as the result of contact with moisture. The senior author has seen injected skates in which a yellow starch mass, injected backward into the mesenteric vein, appeared actually to meet, in the region of the rectal gland, a blue starch mass which had made its way into the rectal network *via* the rectal extension of the cardinal sinus, the two masses clearly lying in the same vessels.

With a view to getting more conclusive evidence as to the relation between the rectal network and the hepatic portal system, the senior author secured some fresh skates of the common species, *R. erinacea* (at Woods Hole, Massachusetts, through courtesy of officials of the United States Bureau of Fisheries and of the Marine Biological Laboratory), and made injections in the following way. A fluid consisting for the most part of water, but containing a small amount of glycerin and colored with finely pulverized insoluble Prussian blue, was injected backward into one of the lateral veins. The rectal network immediately became very fully injected and the blue fluid passed along the mesorectum into the cardinal sinus, in the manner already described. Then a ligature, which had previously been

passed around the narrow posterior end of the rectal extension of the cardinal sinus, was tightened so that further flow of the fluid into the cardinal sinus was prevented. A very light pressure on the syringe was maintained, with the result that the blue fluid appeared in the posterior region of the mesenteric vein and in its posterior branches, whence it passed forward, filling most of the veins on the intestine. The intestinal arteries were then injected, *via* the anterior mesenteric artery, with a fluid similar to that used for the veins, but colored with pulverized carmine. There was no interference or mingling of the blue and red fluids on the intestine, nor was there any evidence that the blue fluid had passed through capillaries into arteries.

The injection of the Prussian blue fluid backward into the mesenteric vein gave similar proof of the continuity of the portal veins and the rectal network. The fluid appeared in extremely fine vessels over the entire intestinal wall and, passing through the rectal network, entered the cardinal sinus and both lateral veins.

To summarize, in *Raia erinacea* and *R. lævis* (see the diagram, Fig. 5): —

(1) There are no veins similar to the large ilio-hæmorrhoidal veins described by Parker for *R. nasuta.*

(2) The two lateral veins have a common origin in a close network of fine vessels distributed over the walls of the rectum and cloaca.

(3) This venous network communicates with the cardinal sinus by means of small vessels lying along the ventral margin of the mesorectum, in the region of its attachment to the rectal gland.

(4) The vessels of the rectal network communicate with the posterior factors of the hepatic portal system as stated by Hochstetter and as thought probable by Parker.

(5) The lateral vein receives the blood from the pelvic fin, there being, in addition to the chief femoral vein, one or two smaller vessels from the fin which open into the lateral vein independently.

The relations of the lateral veins to other parts of the venous system are, therefore, substantially as described by Hochstetter

for selachians in general, except for the connection with the cardinal sinus *via* the cloaco-rectal network.

It is probable that the flow of blood throughout the entire length of the lateral vein is from the cloaco-rectal network and toward the precaval sinus. The steady increase in the diameter of the vein as it leaves the network and curves along the pelvic region points toward this view, as does also the presence, in the pelvic region of the vein, of valves placed so as to impede a posterior flow. The cloaco-rectal network is doubtless an indifferent region as regards flow, the blood passing from it into either the hepatic portal system, the cardinal system, or the

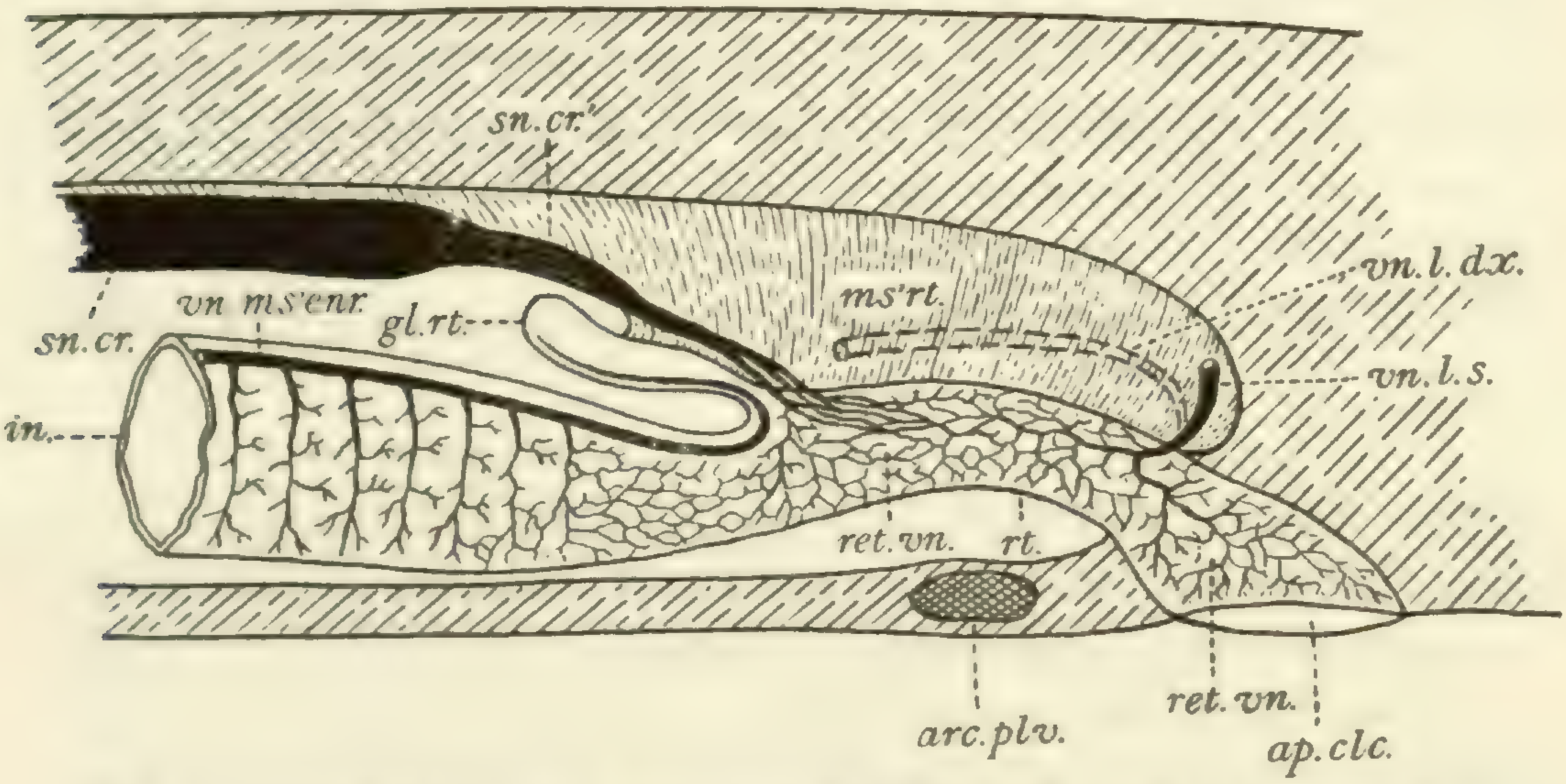

FIG. 5.— Diagrammatic side view of cloaco-rectal region, showing relations of lateral veins, cardinal sinus, and mesenteric vein. *ap. clc.*, cloacal aperture; *arc. plv.*, pelvic girdle; *gl. rt.*, rectal gland; *in.*, intestine; *ms'rt.*, mesorectum; *ret. vn.*, venous network on cloaca and rectum; *rt.*, rectum; *sn. cr.*, cardinal sinus; *sn. cr'.*, rectal prolongation of cardinal sinus; *vn. l. dx*, right lateral vein; *vn. l. s.*, left lateral vein; *vn. ms'enr.*, mesenteric vein.

lateral veins. The blood from both the pectoral and the pelvic fin of one side, therefore, passes to the heart by the same vein.

In two of the dissections made by Mr. Ulrich a suggestive condition was found. The lateral vein, steadily diminishing in caliber, was traced to the wall of the rectum where, at first glance, one would say that it became lost in the network. But close inspection revealed an extremely fine vessel which was virtually the continuation of the lateral vein along the side of the rectum. This fine vessel maintained a fairly straight course through the midst of the rectal network, of which, by reason of

frequent anastomoses, it was really a part, and could be traced forward to the cardinal sinus, except for one or two interruptions where it completely lost itself by branching into the network. If the relatively short gaps in the continuity of this fine vessel were filled in and if the continuous vein thus formed should become nearly as large as the largest part of the lateral vein, the result would be the ilio-hæmorrhoidal vein described by Parker. The condition just described suggests the presence of either an incipient or a rudimentary "ilio-hæmorrhoidal" connection between lateral vein and cardinal sinus. An examination of embryonic stages might yield further information.

The direct connection existing in one case (IV, p. 355) between the renal portal system and the lateral vein is due apparently to the anastomosis of a parietal factor of the renal portal system and one of the parietal branches of the lateral vein. Normally these two sets of veins on the dorsal wall of the abdominal cavity come into close relation at their initial ends. This unusual relation of the lateral vein to the renal portal system is of no great importance in itself, but it is suggestive in connection with the theory that the lateral veins of elasmobranchs are represented in higher vertebrates by the abdominal vein. Just as the two lateral veins in the elasmobranch collect the blood from the walls of the cloaca and from the pelvic fins, so, in the urodele amphibian, the abdominal vein receives the veins from the urinary bladder (which is a derivative of the cloaca), and the two posterior components of the abdominal vein receive the veins from the hind legs. The chief difference is that, in the elasmobranch, the lateral system has no direct connection with the renal portal system, while in the amphibian each of the two posterior components of the abdominal vein is directly connected with the corresponding afferent renal portal vein. Development, as is well known, affords some evidence in favor of the homology. In consequence of the slight abnormality described above, there occurs in the veins on one side of the body in the kidney region of a skate an arrangement similar in all essential respects to that in amphibians. Such an anastomosis of a lateral and a renal portal component occurring on both sides of an elasmobranch and in the posterior region of the

kidneys would yield a condition precisely like that seen in the relations of the abdominal, iliac, and renal portal veins of a urodele. This abnormal skate serves at least to suggest a possible way in which one of the differences in the arrangement of the veins of elasmobranch and amphibian may have arisen.

BIBLIOGRAPHY.

HOCHSTETTER, F.

'88. Beiträge zur vergleichenden Anatomie und Entwicklungsgeschichte des Venensystems der Amphibien und Fische. *Morph. Jahrb.*, Bd. 13, Taf. 2–4, 7 Textfig.

JOURDAIN, S.

'59. Recherches sur la veine porte rénale. *Ann. Sci. Nat.*, 4me Série, Zoöl., Tom. 12, pp. 134–188, 321–369, 5 pls.

MONRO, A.

:85. The Structure and Physiology of Fishes. Edinburgh, 1785, 128 pp., 44 pls.

PARKER, T. J.

'81. On the Venous System of the Skate (*Raja nasuta*). *Trans. and Proc. New Zealand Inst.*, vol. 13, pp. 413–418, 1 pl.

PARKER, T. J.

'86. On the Blood-Vessels of *Mustelus antarcticus*. *Phil. Trans. Roy. Soc. London*, vol. 177, part 2, pp. 685–732, pls. 34–37.

PARKER, T. J.

'95. A Course of Instruction in Zootomy (Vertebrata). Macmillan, London and New York, xxiii + 397 pp., 72 figs.

RAND, H. W.

:05. The Skate as a Subject for Classes in Comparative Anatomy: Injection Methods. *Amer. Naturalist*, vol. 39, pp. 365–379, fig. 1.

ROBIN, C.

'45. Vaisseaux lymphatiques chez les poissons. *Revue Zool. par la Société Cuvierienne*, Paris, Tom. 8, pp. 224–233, 461.

CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE. E. L. MARK, DIRECTOR. No. 166.

THE SKATE AS A SUBJECT FOR CLASSES IN COMPARATIVE ANATOMY; INJECTION METHODS.

HERBERT W. RAND.

THE selection and obtaining of material for the laboratory work of classes in zoölogy, and the best methods of treating that material, are matters of considerable importance to those having such work in charge. My use of the skate for several years past has impressed me with the belief that it is, in some respects, peculiarly adapted for use in the laboratory work of classes in the comparative anatomy of vertebrates. If I am not mistaken, the advantages of the skate for this purpose and the practicability of using it are not always fully realized, especially by teachers who are situated at some distance from the sea. In view of this fact, I think it worth while to call attention to certain points wherein the skate seems to me to be a superior subject for laboratory work. In addition, I shall consider methods of injecting the circulatory system of this fish.

If a student in comparative anatomy is to study a fish as a representative of the class, obviously it should be one which exhibits as nearly as possible primitive vertebrate conditions, — therefore an elasmobranch. If an amphibian is to follow the fish, it should, of course, be one of the tailed amphibians rather than the highly specialized frog. The elasmobranch, in its general anatomy, is much more directly and closely comparable with the urodele than is any teleost. To start a student in vertebrate anatomy on the dissection of a teleost and to follow that with the frog, as a representative of Amphibia, is as poor a program as could be arranged, if it is the intention that he should

see for himself something of the main course in the evolution of the structure of higher vertebrates. The study of types situated near the main line of vertebrate descent is to be preferred to the study of extremes of specialization. It seems to me to be questionable wisdom to let enthusiasm for local fauna lead to the selection of a teleost, for class study, provided that marine material is obtainable, and provided further that only one representative of Pisces can be studied.

Among the elasmobranchs, the sharks depart less conspicuously from primitive conditions than the rays and therefore, theoretically, the dogfishes are to be preferred to the skates for general laboratory purposes. The dorso-ventral flattening of the skate, however, gives it a certain superiority as a subject for dissection. As a result of the flattening, most of the organs of the animal are much more easily accessible than they are in the dogfish. This advantage is of particular importance when it comes to the injection and dissection of the blood-vessels.

The abdominal cavity of the skate is completely exposed with a minimum of cutting. This cavity is a broad and very shallow one so that, its ventral wall having been removed, a slight displacing of viscera brings all its organs immediately into view and renders its chief blood-vessels very easy of access.

It is a consideration of no small moment that the skate, during injecting and dissecting operations, lies in the position most favorable for work — that is, flat on its back — without any special device for holding it there, while it is not always easy to support a dogfish in a desired position.

In the dissecting and study of the circulatory organs, the flattening of the skate is especially advantageous, because, one might say, it tends toward the projecting of the blood-vessels into one plane, resulting in an almost diagrammatic arrangement of them.

A practical point which will often lead to the selection of the skate, if elasmobranch material is to be used, is the fact that skates can be obtained during a large part of the year when dogfish can not. Mr. F. T. Lane, of Rockport, Massachusetts, in response to my inquiry, writes me that he can catch skates off Cape Ann at any time of the year, except during storms,

whereas dogfish can be taken in abundance only during June, July, and August, and sometimes in September. No dogfish are to be caught, he says, from the first of December to the first of May. Also in reply to inquiries of mine, Dr. F. B. Sumner, director of the laboratory of the Woods Hole station of the United States Bureau of Fisheries, states (largely, he says, on the authority of Mr. Vinal Edwards, collector for the station) that skates can be taken in the vicinity of Woods Hole at any time of year except in January, February, and March. Smooth dogfish (*Mustelus canis*) "can be taken in considerable numbers from the latter part of June till November first, being most abundant soon after their appearance late in June," while spiny dogfish (*Squalus acanthias*) are abundant only in May and early June. Neither species of dogfish can be taken in that region from the middle of November until the first of May. Similar statements as to the occurrence of dogfish and skates are made by Dr. Hugh M. Smith ('98) in his list of "The Fishes Found in the Vicinity of Woods Hole."

It appears from the foregoing statements that, so far as the New England coast is concerned, fresh skates, suitable for injection purposes, may be had throughout the greater part of the year, or possibly throughout the whole year, while fresh dogfish can be obtained during not more than five, or possibly six, months of the year. Furthermore, the dogfish are most abundant and most easily taken during the summer months when they are least wanted for laboratory purposes in schools and colleges, except as they may be preserved then and stored for future use. To be sure, dogfish may be collected and injected in the summer and preserved for use later in the year. But, to my mind, there are serious objections to giving a student his animals already injected. He should make his own injections. The injecting of the animal which he is to dissect gives the student information which he will not get so well in any other way, besides being a valuable means of developing skill in operating.

As regards the practicability of shipping fresh elasmobranch material to points distant from the coast, there is no sufficient reason why, in these days of rapid transportation, such material

cannot be had by almost any institution in the country, however remote from the coast. Fish properly packed, so as to secure coolness and freedom from too great pressure, will endure well several days' transportation, especially in the cooler seasons of the year. Skates which are intended for injecting for non-histological purposes are not injured by freezing, provided that they are not exposed to alternate freezing and thawing.

A point of minor importance is the fact that it is easier to secure good preservation of skates than of dogfish. The flattening of the skate's body facilitates the penetration of the preserving fluid to the deep organs. Furthermore, to get sexually mature animals, it is necessary to use dogfish of such large size that the preservation and storing of material for a large class become a serious problem. The same number of small sexually mature skates makes a much less bulky mass of material.

The objection that the skate is a highly specialized elasmobranch does not apply, to any great extent, to its internal anatomy. The specialization involves chiefly the general form of the body. The skeleton and muscles are the systems most affected. The remaining organs undergo relatively unimportant changes in position incident to the flattening of the body. In their essential morphological characters and relations they are closely comparable to those of the shark-like elasmobranchs. From a practical point of view, it might be said that the specialization of the skate is in the direction of adaptation for laboratory purposes.

The plan which has been followed for several years past in the laboratory of vertebrate comparative anatomy at Harvard University seems to me to be an excellent one. The student first makes a general dissection of the dogfish, exclusive of the blood vessels, then injects a fresh skate for the study of the circulatory system. By this arrangement he becomes familiar with the anatomy of the more primitive elasmobranch and studies a typical elasmobranch circulatory system under conditions far more favorable than those offered by the dogfish. At the same time, his familiarity with the dogfish enables him to detect the essential elasmobranch characteristics in the skate and to comprehend the nature of its specialization. Thus, he is

given an opportunity for observing, in an appreciative way, a remarkable case of modification of form. If the student's main work is on the skate, he should at least be given an opportunity to compare skate and dogfish far enough to make clear to him the character of the skate's departure from the more primitive conditions.

Injection Methods.

Injection of the Veins of the Skate.— What I have to say about the injection of the veins of the skate is with special reference to the best method by which this operation may be performed by students who have had little or no experience in such work. It is assumed that the injecting is to be done by means of an ordinary hand syringe.

A complete injection of the systemic veins of the skate is difficult to obtain, even under the most favorable circumstances, partly because the veins are well provided with valves which impede the flow of the injection mass in a direction the reverse of that of the blood-flow, and partly because of the presence of large thin-walled sinuses, which are likely to rupture before the injection mass can be forced into the smaller vessels and those more remote from the point of injection.

The vessels most accessible for the injection of the systemic veins are the postcardinal veins in their renal region, the venous sinus, and the lateral veins. Parker ('95) recommends introducing the injection mass at the venous sinus, the flow of the mass being directed backwards, or away from the heart. An injection directed forward into the hinder or renal part of one of the postcardinal veins has been employed with more or less success. In my opinion, however, injection by way of one of the lateral veins possesses certain advantages over either of the other methods.

The injection of the renal division of the postcardinal vein is objectionable for two reasons. In the first place, it is very difficult to dissect out the vessel. It lies under the peritoneum in a loose mass of connective tissue, and unless the operator is fairly skillful, the cannula is quite likely to be pushed into lymph

spaces or into any opening other than the proper one. In the second place, an injection mass entering by way of the renal end of the postcardinal vein passes directly to the great thin-walled cardinal sinus. No other veins can fill until the pressure in the cardinal sinus has increased sufficiently to force the mass on into the smaller and more remote spaces. This involves great danger of bursting the wall of the cardinal sinus. In practice, the danger may be lessened by exerting external pressure upon the sinus, either with the hand or by other means, so as to prevent its becoming distended to its utmost capacity.

The venous sinus is a point more favorable for injection than the postcardinal vein, so far as the filling of the vessels is concerned. If the injection mass is directed backward into one arm of the venous sinus, the initial pressure of the fluid is exerted almost directly at the ends of the several main venous trunks which, other things being equal, stand equal chances of filling. In practice, however, this method has been found objectionable when attempted by an unskillful student (and since the fish is usually the first animal injected by a student in comparative anatomy, he is quite likely to be unskillful through lack of experience). The venous sinus is not very favorably situated for the injecting operation. Great care is required lest the cannula be pushed against the delicate wall of the sinus so as to rupture it. Poor judgment in controlling the pressure on the syringe results in the bursting of the sinus, and often the thin-walled auricle is injured in the course of the operation. In the case of a preparation for demonstration or museum purposes, the cutting of the venous sinus is, in itself, objectionable.

The difficulties which are met in the injecting of the postcardinal vein or venous sinus are largely or wholly avoided by the use of the lateral vein. The lateral vein is a large vessel extending along the entire length of the side wall of the abdominal cavity and lying just beneath the peritoneum. It is conspicuous in skates which have been dead not more than a day or two, because of the blood contained in it. It is not necessary, as in the case of the renal vein, to dissect out the vessel for injection. The following method will be found practicable.

Open the abdominal cavity and note the position of the lateral

veins. Then, at a region about midway of the length of one lateral vein, and in a plane transverse to the long axis of the fish, make an incision into the muscle of the lateral wall of the abdominal cavity, carrying the incision across the lateral vein and somewhat dorsal to it (see the figure, page 377). The incision must be deep enough to admit of pressing apart the masses of muscle either side of the cut in such a way as to make easily accessible the two cut ends of the lateral vein. Immediately, then, before the loss of the blood contained in the vein shall have made it difficult to see the vessel, thrust a probe or a coarse bristle forward into the cut end of its anterior division and another backward into its posterior division. A mass which "sets" quickly may be injected without tying the cannula into the vein. For this purpose it is desirable to use a cannula of a size sufficient nearly to fill the lumen of the vein. Such a cannula, with the injection apparatus attached, may be inserted successively into the two cut ends of the vein and held firmly in place with the fingers during the process of injecting. If it is desired to tie the cannula in place, the muscle may be cut away from around the cut end of the vein so as to leave about one centimeter in length of the vessel projecting, with more or less tissue attached to it. A ligature may then be passed around this small projecting mass of tissue, including the vein, and, the cannula having been inserted, the ligature is tightened upon it.

The fluid which is injected into the anterior division of the lateral vein passes directly to the corresponding precaval (Cuvierian) sinus, whence it may pass into all the chief venous trunks of that side except as impeded by valves. It passes also, by way of the venous sinus, directly across to the opposite precaval sinus, whence it may enter the vessels of that side of the body. The cardinal and hepatic sinuses afford other, but less direct, routes for the passage of the fluid from one side to the other. In practice, this method usually results in the filling of both lateral veins and at least the proximal ends of the several brachial trunks. The mass fills also the postcardinal veins, including their posterior inosculation, the hepatic sinus and veins, the cardinal sinus, and the proximal ends of the inferior jugulars.

The precardinal veins, however, are rarely injected by this or by any other method, except that of direct injection of each precardinal from its anterior end, — an operation which is not practicable for anyone who is not familiar with the position of the vein.

The filling of the cavities of the heart may be prevented or controlled by means of ligatures tied around the heart in the regions of the sinu-auricular and auriculo-ventricular apertures.

The injection into the posterior division of the lateral vein fills the posterior connections of that vein, including the veins from the pelvic fin (see Rand and Ulrich, :05).

In brief, the advantages of injection *via* the lateral vein are as follows: (1) the lateral vein is a sufficiently large vessel and most easy of access; (2) its preparation for injection is a simple operation, requiring no nice dissection nor other delicate technique; (3) it is a relatively narrow and strong-walled vein, not easily broken by the point of a cannula, and capable of withstanding the initial pressure of the injection; (4) it conveys the mass first to the precaval sinus, whence the chief vessels may fill; (5) the weak-walled cardinal sinus is remote from the point of injection; (6) maximum filling of the systemic veins is secured by a single operation.

An injection of the renal portal system is secured easily by cutting across the tail at least four or five centimeters back of the cloacal aperture and injecting forward into the caudal vein. A taper-pointed glass cannula may be inserted carefully into the cut end of the vessel and pushed in until the end of the vein is tightly closed. During the progress of the injection the cannula must be held firmly in place. When the cannula is withdrawn, the escape of the fluid may be prevented by jamming a bit of cotton into the end of the vein.

The hepatic portal system is best injected through the mesenteric vein. To secure a full injection upon the intestine the vein must be injected backward as well as forward. Parker ('95, p. 48) injects the duodenal vein, thus getting a complete injection at one operation. This is, indeed, an advantage. But, in small skates, the greater size of the mesenteric vein, and the fact that it is so much more accessible than the duodenal vein,

make the two-way injection of it usually less difficult to the student than the single injection of the duodenal vein.

Injection Masses. — For the injection of the vessels of the skate I have used an injection mass which is merely a slight modification of well known masses, but one which may be found to possess peculiar virtues for certain special purposes. Among the injection masses suitable for purposes of gross dissection, the cold or unboiled starch mass of Pansch ('77, '81; see Whitman, '85, pp. 223–225) is doubtless best for general laboratory use, especially where, in the case of a large class, many injections must be made rapidly. It is inexpensive, easy to use, and gives results satisfactory for temporary demonstrations. It is, however, not perfectly adapted for permanent demonstrations or museum preparations, owing to the fact that it does not "set" or harden. The particles of starch remain in a discrete condition so that, in the event of any injury to the wall of an injected vessel, the mass may leak out and discolor the surrounding tissue. The starch mass is poorly adapted for the injection of the venous system of the skate because it is practically impossible to dissect the thin-walled and irregularly shaped vessels without an occasional slight injury, which gives rise to annoying leakage of the mass.

Recently I had need of a mass which should acquire, after injection, a fairly stiff consistency without becoming brittle, which should not pass through capillaries, and which should be convenient to use. Some modification of the gelatin method seemed most likely to satisfy these conditions. A gelatin mass with the coloring matter in solution, as ordinarily prepared, is designed to pass capillaries. After some unsatisfactory experiments with gelatin colored by means of pulverized carmine or insoluble Prussian blue in suspension, it was suggested by Mr. J. A. Long, who was working with me, that starch be mixed with the melted gelatin to prevent its passing into the capillary vessels. We had at hand a supply of the unboiled starch mixture in several colors. The method which we used with success at that time consisted in stirring into the melted gelatin about one fourth its volume of the thick starch mass, which always settles to the bottom of a jar containing the raw starch mixture.

Thus, the starch and the color were added both at once. In the absence of the prepared starch mixture, a similar result may be attained as follows.

Mix together some of the grocer's pulverized cornstarch and about one seventh its volume of a suitable finely powdered coloring matter (carmine, insoluble Prussian blue, chrome yellow, chrome green). Add a little cold water to the mixture and convert it into a thick paste. Into the melted gelatin stir one third or one fourth its volume of the colored starch paste. The proportions of the mixture may be varied, as occasions demand. I have found the following formula convenient: —

Melted gelatin	75 volumes.
Dry cornstarch	22 "
Dry color	3 "

For non-histological purposes it is, of course, unnecessary to use the finer grades of gelatin, such as photographic gelatin. Any ordinary culinary gelatin serves equally well, besides being always easily obtainable and less expensive. A mass of good stiffness for injection purposes is obtained by using 1 gram of dry gelatin to every 7 or 8 ccm. of water. If the vessels to be injected contain much blood, the gelatin solution must be of such strength that the mingling of the blood with it will not prevent the hardening of the mass. It is better not to inject the veins of a skate immediately after the death of the animal, for then the sinuses contain a large quantity of blood. If the fish is kept in a cool place for about two days after death, the greater part of the blood will have disappeared from the vessels. At the same time, the walls of the vessels will have relaxed so that the injection is more likely to pass into the smaller vessels. This latter consideration is of more importance with reference to the arteries than to the veins.

As regards the convenience of the starch-gelatin method, the warming of the animal, preliminary to the injection, is unnecessary. The chief difficulty, therefore, which attends the gelatin method as ordinarily used for histological purposes, is obviated. I have obtained good starch-gelatin injections of the entire circulatory system of the skate, working in a room at

ordinary temperature (20° C.) without warming the animal above the temperature of the room. The melted gelatin was slightly superheated, and the heavy brass syringe, with rubber tube and cannula, was heated by immersing in hot water to a temperature about as high as consistent with comfort in handling. By these means, the starch-gelatin was introduced into the blood-vessels at a temperature considerably above its solidifying point. The warm fluid penetrates into the smaller and remote vessels before becoming cooled sufficiently to harden, giving quite as full an injection of the finer vessels as the cold starch mass ever does.

The skates which I have injected with starch-gelatin were immersed, immediately after injection, in three or four percent formalin, which, having been freshly prepared with tap water, was considerably cooler than the room temperature. The starch-gelatin promptly solidified into a firm mass having the consistency characteristic of stiff gelatin.

The starch-gelatin method described above gives results entirely satisfactory for purposes of gross dissection. The method may be used under any conditions where the unboiled starch mass might be used, but where a mass of the consistency of gelatin is to be preferred. The advantage of the starch-gelatin as compared with the raw starch lies in the fact that the mixture "sets" and, therefore, will not escape, however much the vessels may be cut. The advantage, for the purposes mentioned, of the mixture as compared with pure gelatin is in the fact that the starch causes the mass to stop at capillaries, thus preventing danger of the injection passing from one set of vessels into another. Finally, the method is not a particularly troublesome one, since the warming of the animal itself — usually the greatest inconvenience attending the use of any warm injection mass — may be omitted. The superiority of the starch-gelatin is most marked in the injecting of a blood-system containing large thin-walled sinuses, as in the case of the venous system of the skate. Its advantages over plaster of Paris for this purpose, are obvious and it is scarcely more troublesome to use.

The injection of the arteries of the skate is a comparatively simple matter. The afferent branchial vessels may be injected

through the arterial cone, as directed by Parker ('95, p. 48). For the systemic arteries, Parker makes a single injection at the duodenal artery. But, unless one is dealing with a large skate, I have found it better to inject the anterior mesenteric artery (see Fig. 1), in spite of the fact that it is necessary to inject it backward (to secure an injection upon the intestine) as well as forward. The greater size of the anterior mesenteric artery and its accessibility, lying, as it does, along the very edge of the mesentery, are advantages which more than offset the necessity of injecting it both ways. As for details, such as the form of the cannula and the manner of inserting it, I should consider Parker's method applicable to a very large fish only. The caliber of the anterior mesenteric artery in skates of small or medium size is such as to require the use of a cannula with a slender slightly tapering tip. By Parker's method, a cannulafull of air is injected into the vessel. To avoid this, the cannula should be attached to the syringe and filled with the fluid before being inserted into the vessel.

In the accompanying figure of the skate I have indicated the points at which the injections may best be made, to secure as nearly as possible a complete injection of the blood vessels in three colors. The mesenteric vessels are conveniently reached by turning the stomach forward (so that, as the fish is viewed from the ventral side, the dorsal aspect of the stomach is seen) and pulling the digestive tube over to the animal's right side in such a way as to stretch out flat the mesentery. The figure represents the digestive tube in this position.

The several injections may well be made according to the following plan. Whatever the order, the arteries should be injected before the veins.

ARTERIES.

1. *Arterial cone* - - - - - - forward - - - blue starch-gelatin or starch.
2. *Anterior mesenteric* forward - - - red " " " "
3. " " backward - " " " " "

VEINS.

Hepatic Portal.

4. *Mesenteric* - - - - - - - - forward - - - yellow starch-gelatin or starch.
5. " - - - - - - - - backward - " " " " "

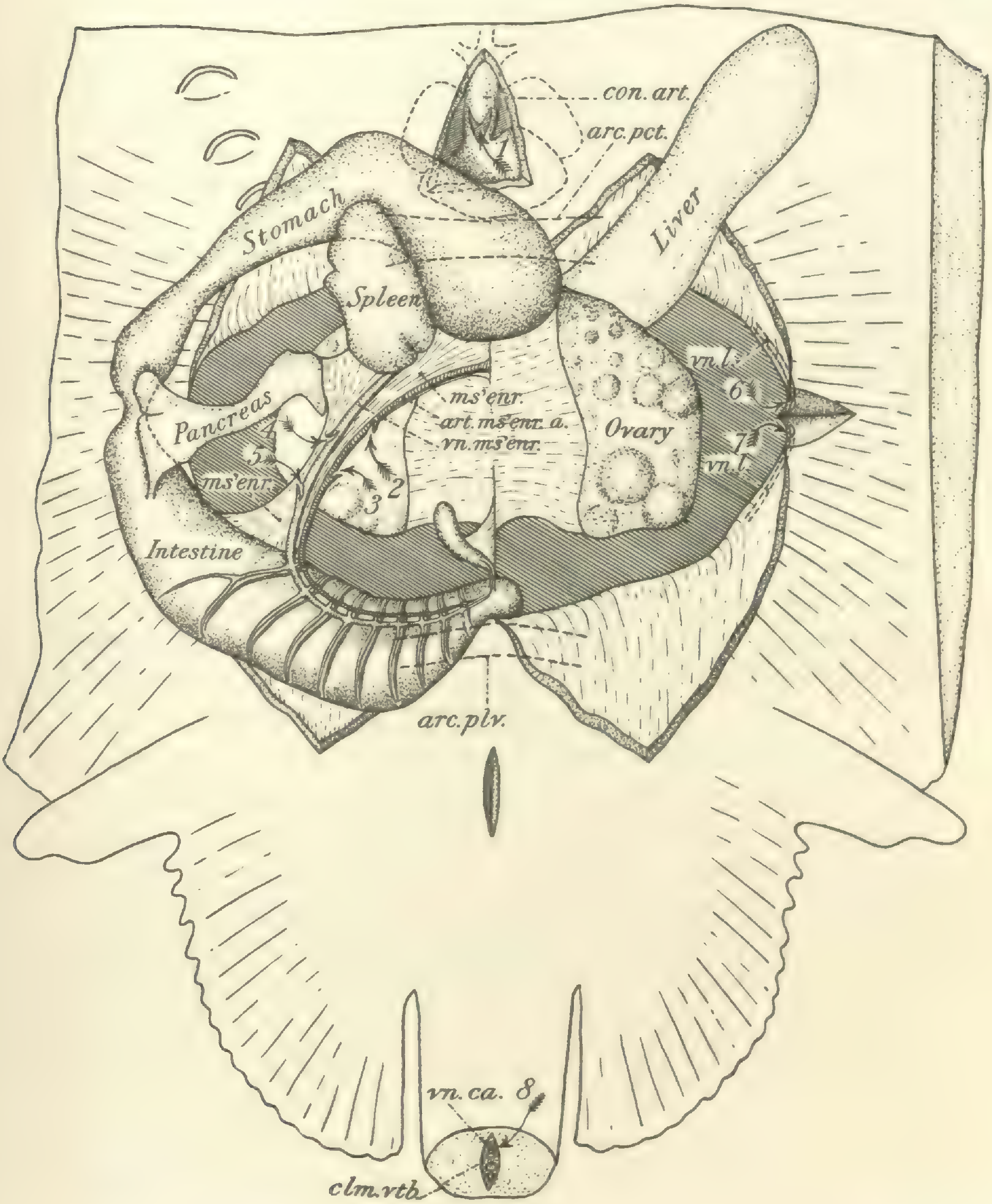

FIG. 1.—The injecting of the blood vessels of the skate. The arrows indicate the points at which the injections are to be made and the direction in which the cannula is to be inserted. The numbers attached to the arrows refer to the order of injecting given on page 376. *arc. pct.*, pectoral girdle; *arc. plv.*, pelvic girdle; *art. ms'enr. a.*, anterior mesenteric artery; *clm. vtb.*, vertebral column; *con. art.*, arterial cone; *ms'enr.*, mesentery; *vn. ca.*, caudal vein; *vn. l.*, lateral vein; *vn. ms'enr.*, mesenteric vein.

Systemic.

6. *Lateral* --------- forward --- blue starch-gelatin.

7. " ----------- backward - " " "

Renal Portal.

8. *Caudal* ----------- forward -- yellow starch-gelatin or starch.

If it is desired to use gelatin for only the systemic veins, where it is of greatest advantage, the arteries and the two portal systems may first be injected with cold starch and then the systemic veins with gelatin alone, for it is unnecessary to add starch to the gelatin to prevent its passing capillaries when all of the vessels beyond the system which is being injected are already filled.

Are so many as eight separate injections necessary? My experience has been that to decrease the number of operations is to increase their difficulty and to render the results less satisfactory. A mass injected into the systemic veins may pass through the heart into the afferent branchial vessels. Yet I have found it difficult to secure a full injection of the finer afferent vessels of the gills except by injecting directly into the ventral aorta itself. A perfectly fluid mass injected into the hepatic portal vessels or into the caudal vein may be made to fill the greater part of the venous system. But it is a great advantage in the dissection to have the hepatic portal and renal portal vessels distinguished from the systemic veins by a different color. The difference in color serves to emphasize to the mind of the student in a forcible way the nature of the relation between the portal systems and the systemic veins. The simplest way of securing the color difference is to inject each portal system separately. All the systemic arteries may be injected from the caudal artery at a single operation, but students succeed better with the two-way injection at the anterior mesenteric artery. In short, it is better to make eight easy operations than to make two or three of greater difficulty and less certainty.

BIBLIOGRAPHY.

PANSCH, A.

'77. Kalte Injection mit Kleistermasse. *Arch. f. Anat. u. Physiol.*, Jahrg. 1877, Anat. Abth., pp. 480–482.

PANSCH, A.

'81. Noch einmal die Kleisterinjection. *Arch. f. Anat. u. Physiol.*, Jahrg. 1881, Anat. Abth., pp. 76–78.

PARKER, T. J.

'95. A Course of Instruction in Zootomy. (Vertebrata.) London and New York, xxiii + 397 pp., 74 figs.

RAND, H. W., AND ULRICH, J. L.

:05. Posterior Connections of the Lateral Vein of the Skate. *Amer. Naturalist*, vol. 39, pp. 349–364, 5 figs.

SMITH, H. M.

'98. The Fishes Found in the Vicinity of Woods Hole. *Bull. U. S. Fish Commission*, vol. 17, pp. 85–111.

WHITMAN, C. O.

'85. Methods of Research in Microscopical Anatomy and Embryology. Boston, viii + 255 pp., 37 figs.

FOSSIL CRABS OF THE GAY HEAD MIOCENE.

JOSEPH A. CUSHMAN.

During the summers of 1903 and 1904 the writer made two trips to Gay Head for the purpose of obtaining fossils, especially those of the crabs so abundant there. The fossil crabs are found in the greensand layer in close relation to the so called "osseous conglomerate." At the northern end of the exposure, the crabs occur in a layer about six inches below the conglomerate, which is itself at this point a very narrow band. In this greensand layer which here is of a very dark, almost blackish green color when first dug out, the crabs lie in a natural position in the bed. That is, the crabs are in a position with their dorsal and ventral surfaces in the plane of the layer which contains them. As the edge of the layer is here exposed in the cliff and tilted at a very considerable angle, the edges of the crabs are struck in digging them out. They occur in very hard concretions, often entirely covered or as frequently, with a portion of the carapace or legs showing at the surface. The shelly portions of the crabs are decidedly black in color. The calcareous matter is still left, however, and entirely dissolves with effervescence in acid.

In another portion of the cliff, a short distance north of the lighthouse, the crab layer slopes in the opposite direction and is of a creamy white color. The crabs and the material in which they are imbedded are in consistency almost like cheese when dug out. This material is so soft that it can be easily cut with a knife. Upon exposure to the air the material quickly hardens and shrinks in drying, usually cracking considerably. The crab remains are here beautifully preserved in their details, the small papillæ on which the hairs are set being as perfect as they could have been in the living animal.

In certain cases in the larger concretions, there are obtained

remains which give a very good general idea of the crab as a whole. These larger concretions also have the various parts excellently preserved as will be noted in the description.

Dr. Edward Hitchcock was the first definitely to publish the occurrence of the crab remains at Gay Head. He spoke of them in his earlier reports on the geology of Massachusetts. In the Final Report of 1841, he speaks as follows: —

"Crustacea. In the green sand at Gay Head we meet with well-characterized specimens of the genus Cancer, although they are in general much broken, showing that they originally belonged to a formation which was abraded or destroyed anterior to the production of the green sand. The interior part of the specimen consisted of argillaceous matter, probably containing a large proportion of oxide of iron; but the covering of the animal still retains its black shining color, although apparently carbonaceous. The broken state of nearly all the specimens, renders it difficult to determine whether they belonged to more than one species, although they probably did: and for the same reason I have thought that drawings would not be of use."

In 1844, Sir Charles Lyell remarks at some length concerning the structure and fossils of the Gay Head exposure, both in the *Proceedings of the Geological Society of London* and in the *American Journal of Science*. In the latter (vol. 46, 1844, p. 319) he refers to the crab remains in the following words: —

"Crustacea. A species considered by Mr. Adam White as probably belonging to the genus Cyclograpsus, or the closely allied Sesarma of Say, and another decidedly a Gegarcinus."

In 1863, Dr. William Stimpson described *Archæoplax signifera* from the Gay Head greensand and mentioned that there is another species although he did not attempt to name it (*Boston Journ. Nat. Hist.*, vol. 7, pp. 583–589, pl. 12).

In 1900 (*Proc. Amer. Acad. Arts and Sci.*, vol. 36, no. 1, pp. 1–9, pls. 1–2), Professor Alpheus S. Packard describes a new fossil crab, *Cancer proavitus*, from Gay Head and gives a few notes and several photographs of *Archæoplax signifera* Stimpson.

Specimens representing the latter species were especially abundant in the material collected during the last two summers.

These show many points of structure not heretofore described. The material is in the museum of the Boston Society of Natural History, and is referred to by number. The material at the Museum of Comparative Zoölogy at Cambridge was also studied and is also referred to as well as one or two specimens in the teaching collection of the Paleontological Department of Harvard University.

Archæoplax signifera Simpson.

Archæoplax signifera Stimpson, *Boston Journ. Nat. Hist.*, vol. 7, no. 4, April, 1863, p. 584, pl. 12, figs. 1–4; Dall, *Amer. Journ. Sci.*, vol. 48, 1894, p. 297; Packard, *Proc. Amer. Acad. Arts and Sci.*, vol. 36, no. 1, July, 1900, p. 7, pl. 1, fig. 4, pl. 2, figs. 1–3.

Carapace. — In the specimens the length of the carapace varies from 1 to 2.5 inches, in greatest breadth from 1.2 to 2.75 inches, and in posterior breadth from 0.75 to 1.8 inches. The superior outline along the median antero-posterior line is decidedly curved as noted by Stimpson. This is shown in an outline side-view of a typical carapace (Pl. 1, Fig. 1). A similar view in the median line (Pl. 1, Fig. 2) shows at the slope at the sides and the depressions at each side of the median portion. The surface of the carapace is smooth, finely punctate or granular, the coarser granulation being in definite portions of the central region as well as of the anterior and lateral regions. The color pattern of the carapace is very well made out in several specimens. In the great majority of the specimens it is shown by a difference in smoothness and in luster of the surface, but may be seen as black markings against a dark gray background, as in Pl. 2, Fig. 3, or best of all on the under side of the upper surface as black markings on a very light brownish white background (Pl. 2, Fig. 4). Here the markings stand out with remarkable clearness. There is considerable variation in the markings of this species but all follow the same general pattern. The central lunate markings are important as a means of orienting any large or small part of a specimen of this species which

shows them. The variation in the central markings is shown in the two figures. In certain specimens examined the two sides of the same specimen varied much from each other.

As a whole the carapace is quadrangular, considerably broader in front than behind. The front angles have four teeth as described by Dr. Stimpson. Three of these are large, the first, second, and fourth, while the third is decidedly smaller. The orbits, as described, occupy about one third the breadth of the front of the carapace. The border is entire and raised, and is composed of crowded granules.

The front is nearly one fourth the width of the carapace and has a somewhat different form from that figured by Dr. Stimpson as a comparison of the figures will show. Excellent specimens of this part were obtained showing the complete form. There are two lateral lobes on the anterior border and a median lobe which is cut on the median line, making it emarginate. The front as a whole is bent downwards as shown in Pl. 1, Fig. 1. In the restoration it is drawn as though slightly raised to give its true shape (Pl. 1, Fig. 3).

In the specimens broken from large concretions the eyes have very frequently been excellently preserved. They have a prominent basal joint, with an expanded cylindrical outer portion of the shape shown in the figure. It seems strange that Dr. Stimpson did not obtain good specimens of the eyes for they have appeared very frequently in the collections of the last two summers.

Of the antennæ little was made out except their position which is but very slightly anterior to the base of the eyes. The bases of the antennæ appear as cross sections and as small bits now and then.

One specimen (Pl. 2, Fig. 5), showed the pair of antennules extending slightly beyond the front, but here again it was impossible to make out much more than their presence and position.

Turning to the ventral side, almost the entire features have now been made out and are included in the synthetic figure (Pl. 2, Fig. 6). The sternum is excellently preserved in a considerable number of specimens. A cast from the white layer showing all the minute tubercles was obtained (B. S. N. H. no. 12,977).

In drying, this specimen has cracked considerably. As a whole the sternum is nearly a plane surface except where it is hollowed in the center to receive the abdomen. The anterior portion, triangular in shape, is usually well separated from the rest. It varies considerably in size and shape. The main part of the large anterior plate is divided into three parts by a Y-shaped combination of sutures as seen in the figure. This is an incomplete division but the sutures are nearly always in evidence. As noted by Dr. Stimpson the "male genital tubercles" are found on the posterior margin of the second segment. These are situated just within the edge of the abdomen so that they are covered by it.

Dr. Stimpson found the abdomen of the male only, but in the collections of the past two years there are a few specimens of the abdomen of the female. The males appear to have been much more common. The male abdomen is approximately as figured by Dr. Stimpson, none of the segments being fused. A figure of the female abdomen is given (Pl. 2, Fig. 10). The third joint from the end is the widest, and there is an abrupt tapering from it toward either end. Of the abdominal appendages but one specimen, and that very incomplete, has appeared (Pl. 2, Fig. 11). This specimen indicates at least two pairs of these appendages.

One specimen (Pl. 2, Fig. 12) shows a cast of the outer maxilliped from which a fairly complete idea of these appendages may be obtained. Several other specimens show the basal joints in place and the minutely tuberculated surface (Pl. 2, Fig. 9).

The front legs are shown in a number of specimens, the basal and outer joints being those most frequently preserved. The teeth on two of the joints as figured by Dr. Stimpson, were not made out. The chelæ have a series of alternating teeth alike in both the left and the right sides. The various joints were more or less ornamented with a color pattern, portions of which are well preserved in a number of specimens. The teeth and the tips of the chelæ are much lighter colored than the other portions. The portion of the shell about the base of the anterior pair of legs has a raised beaded edge. This portion is often broken away and variously placed in some of the specimens.

Of the posterior four pairs of legs we have with the help of one specimen obtained in 1904 (Pl. 2, Fig. 2), a knowledge of all the parts. This specimen had the last four joints of a single leg very well preserved. The main characteristic of these appendages is the great length of the fourth joints. These joints are considerably flattened in some cases but usually appear in cross section as shown in Pl. 2, Fig. 13.

Certain of the specimens preserved in the concretions show the internal characters very well. The doubly triangular skeletal mass shown in Pl. 2, Fig. 5, is often seen perfectly preserved. The divisions of the posterior part of the body are also seen in the same figure. In rare cases the gills are found lying in their cavities. In one case a small piece was taken out, softened and mounted. In this condition it showed the tubes and something of the structure of the gill. Apparently it was simply dried and not in any degree impregnated by mineral matter. A small rod-like mass is often seen when the front is broken away exposing the interior.

Altogether it seems that we now have a very fair knowledge of this Miocene species. In Pl. 1, Fig. 3, is given a restoration of this species from the specimens studied.

Cancer proavitus Packard.

Cancer proavitus Packard, *Proc. Amer. Acad. Arts and Sci.*, vol. 36, no. 1, July, 1900, p. 3, pl. 1, figs. 1–3.

Of all the specimens examined there seems to be but one which is in any way referable to this species. This specimen from the white leached layer already mentioned, consists of the cast of the sternum, abdomen, and outer maxilliped of a small female individual. Its main characters are shown in Pl. 2, Fig. 14. From a study of the type the specimen is referred to this species as it seems to be a Cancer and is from the same bed as was the type of this species. The type was a male and this is in all probability a small female of the same species. It will be at once seen that it cannot be referred to Archæoplax, which has

a very different sternum, abdomen, and outer maxilliped from that shown in the specimen under discussion. This species represented by the male specimen and the hand originally described, and now by this cast of the under side of a female, shows that it must have been far less common than the Archæoplax. Further search, however, should yield more specimens of this species. I am greatly indebted to Dr. Walter Faxon of the Museum of Comparative Zoölogy for help in placing this specimen in its present position, for although its condition would not give its complete relations there was nothing to preclude its being a Cancer.

Many of the Archæoplax had specimens of *Balanus concavus* Bronn attached to the carapace, as has been already noted in a previous paper.

Boston Society of Natural History,
March, 1905.

Explanation of Plates.

Plate 1. Natural size.

Fig. 1. Outline of side view of a typical carapace.
Fig. 2. Outline of front view of section through middle of carapace.
Fig. 3. Restoration of *Archæoplax signifera*, dorsal view.

Plate 2. ¾ natural size.

Fig. 1. Ventral view, sternum and joints of front leg (B. S. N. H. no. 12,946).
Fig. 2. Last four joints of one of the walking legs (B. S. N. H. no. 12,914).
Fig. 3. Color pattern of one side of carapace (M C. Z.).
Fig. 4. Color pattern of small specimen from inside (B. S. N. H. no. 12,969). × 2½.
Fig. 5. Specimen broken open showing antennules, plates of interior, and double triangular plate (B. S. N. H. no. 12,945).
Fig. 6. Synthetic figure from ventral side.
Fig. 7. Portion of hand and finger with teeth (B. S. N. H. no. 12,941).
Fig. 8. Portion of two chelæ, partly broken (B. S. N. H no. 12,942).
Fig. 9. Ventral view of sternum, abdomen, maxilliped, basal joints of legs and portion of chela (M. C. Z.).
Fig. 10. Abdomen of female (B. S. N. H. no. 12,940).
Fig. 11. Specimen showing abdominal appendages (B. S. N. H. no. 12,943).
Fig. 12. Outer maxilliped of right side (B. S. N. H. no. 12,947).
Fig. 13. Outline of section of one of the rear legs.
Fig. 14. *Cancer proavitus*, portion of abdomen, sternum, maxilliped, and basal joints of two legs (B. S. N. H. no. 12,970).

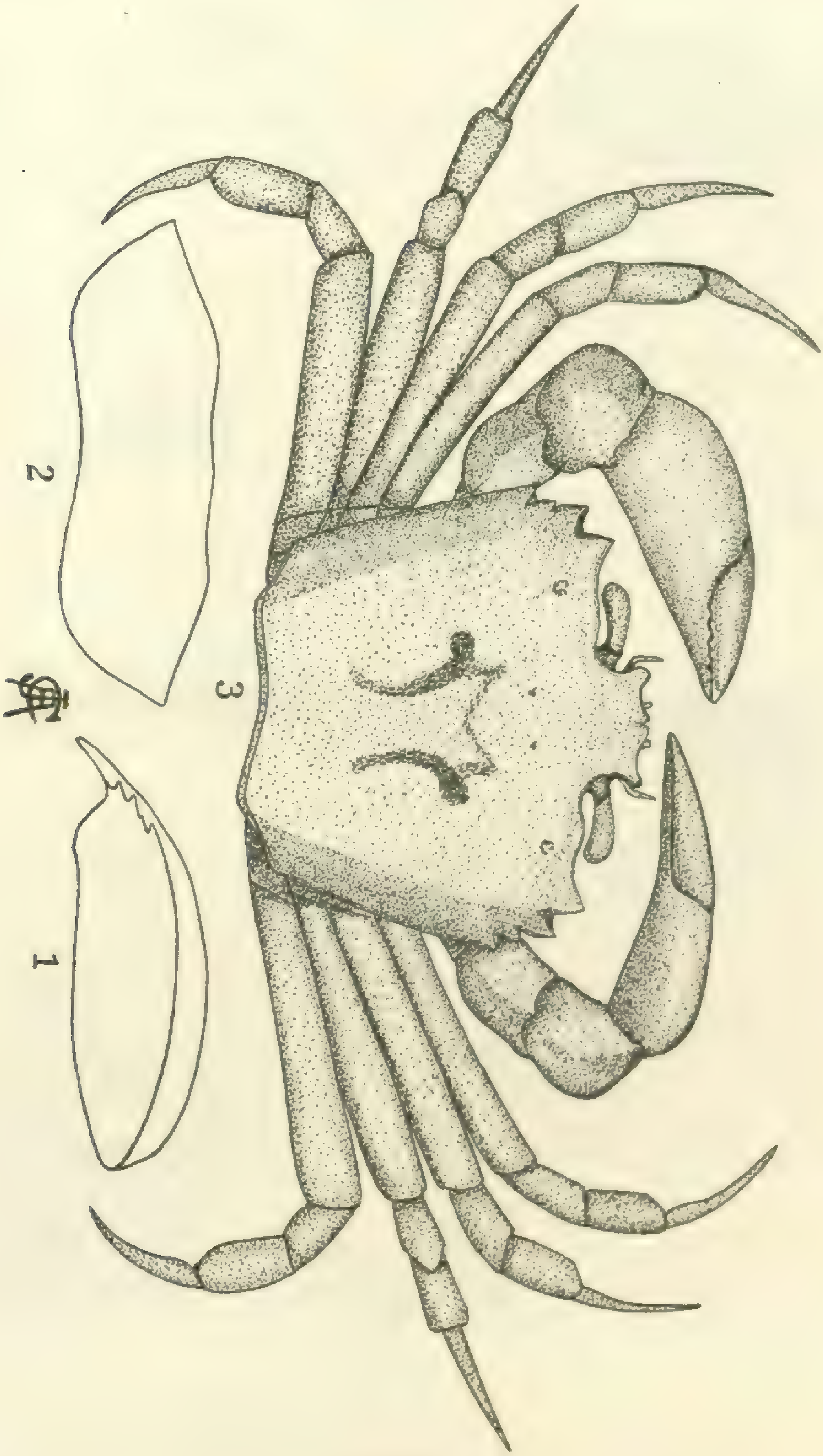

PLATE I.

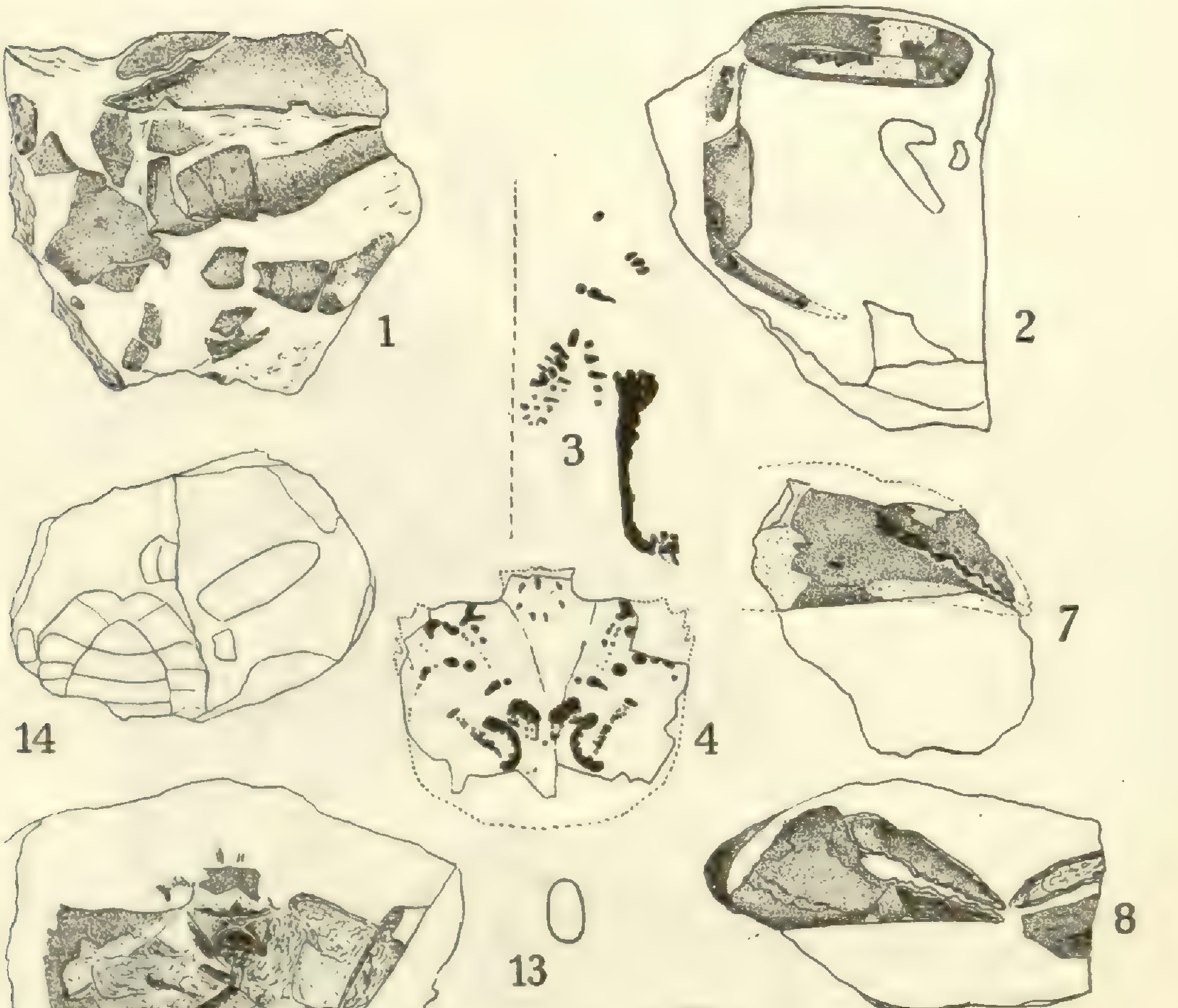

PLATE 2.

CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE. E. L. MARK, DIRECTOR. No. 167.

A CASE OF ABNORMAL VENOUS SYSTEM IN *NECTURUS MACULATUS.*[1]

THEODORE H. ROMEISER.

In all classes of vertebrates variations in the morphology of the circulatory system are by no means infrequent. Indeed, one rarely, if ever, finds two individuals with precisely the same arrangement of the blood-vessels. Even in cases in which the vessels are for the most part symmetrical, the smaller vessels, particularly the veins, are found to vary more or less on opposite sides of the body, as is readily shown by a comparison of the superficial veins of one's own forearms or the backs of the hands.

The literature on abnormalities of the blood-vessels shows that they often may involve even the largest and most important veins of the body, such as the postcava and its tributaries. It has been observed that in the venous system of some vertebrates the cases of variation are more frequent than those of the "normal" condition. Thus McClure (:00 a) finds variations in the opossum of such frequent occurrence and of so definite a character as to suggest probable phylogenetic relations.

The literature on abnormalities of the veins in Urodela shows records of several cases, mostly in European salamanders. Hochstetter ('88, p. 164) describes a condition in *Salamandra maculosa* in which the postcava did not pass through the liver, but was continuous with the much enlarged right posterior cardinal vein, the two forming a single vessel passing straight to the venous sinus. He also briefly mentions similar abnormalities seen in specimens of *Siredon pisciformis.*

Joseph (:01) observed in *Salamandra maculosa* a similar case,

in which, however, it was the left cardinal that was hypertrophied. In another case (also *S. maculosa*) described by Joseph, there were two abnormally large, symmetrical veins on the ventral surface of the liver, one on each side of the suspensory ligament. (Normally, according to Hochstetter, there is but one large hepatic vein, which is in the left half of the liver.) They ended separately in the venous sinus, which was, in his opinion, the enlarged end of the left vein. The right vein he found continuous with the postcava within the liver. According to his description and figures, the postcava entered the dorsal surface of the posterior end of the liver, passed forward through the liver substance, as it does normally, then became continuous with the right superficial vein ventrally, near the junction of the anterior and middle thirds of the liver.

The following anomaly was observed in the veins of a specimen of *Necturus maculatus* injected for dissection of the vascular system. The work was done in connection with the course on comparative anatomy given by Dr. H. W. Rand at Harvard University. Although annually for some years past many of these amphibians have been used for dissection and injection, no similar condition has been noted. This case is of interest, not only on account of its rarity and the profound alterations involving the chief veins of the body, but also because it is, so far as I know, the first instance of the kind observed in Necturus. Moreover, it differs markedly from all similar cases previously reported. Before giving an account of this abnormal condition, it may be well to describe briefly the normal arrangement of the corresponding veins.

The postcava (Fig. 1) begins as a median trunk lying between the kidneys; passes anteriad ventral to the aorta, which it leaves at a point near the posterior border of the liver; bends ventrad to enter the dorsal surface of the posterior end of the liver, through which it passes anteriad and within which it receives the hepatic veins; emerges on the ventral surface of the anterior end of the liver; bifurcates, then reunites and ends in (or rather is continuous with) the venous sinus at the point where the ducts of Cuvier enter laterally. The right and left posterior cardinals arise from the convexity of the bend in the postcava

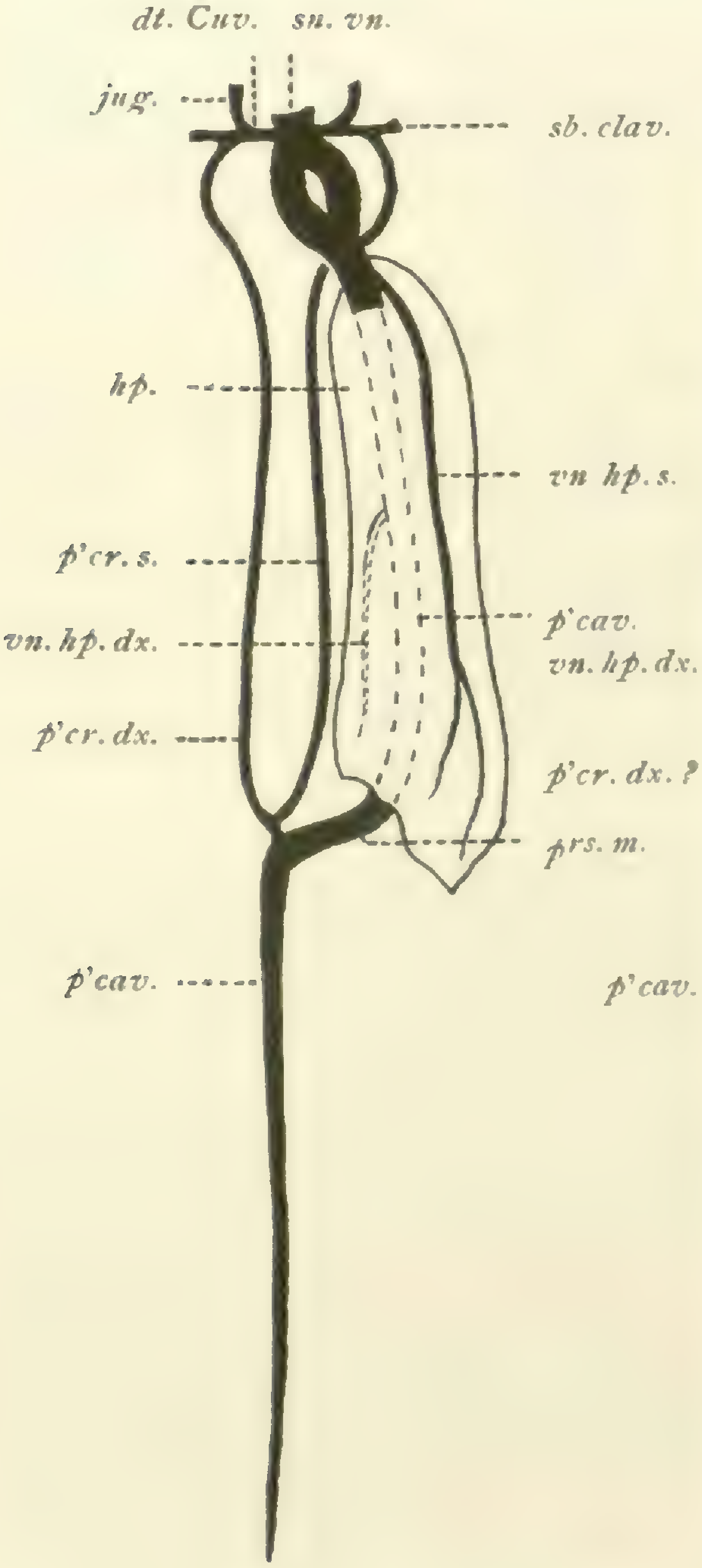

FIG. 1.

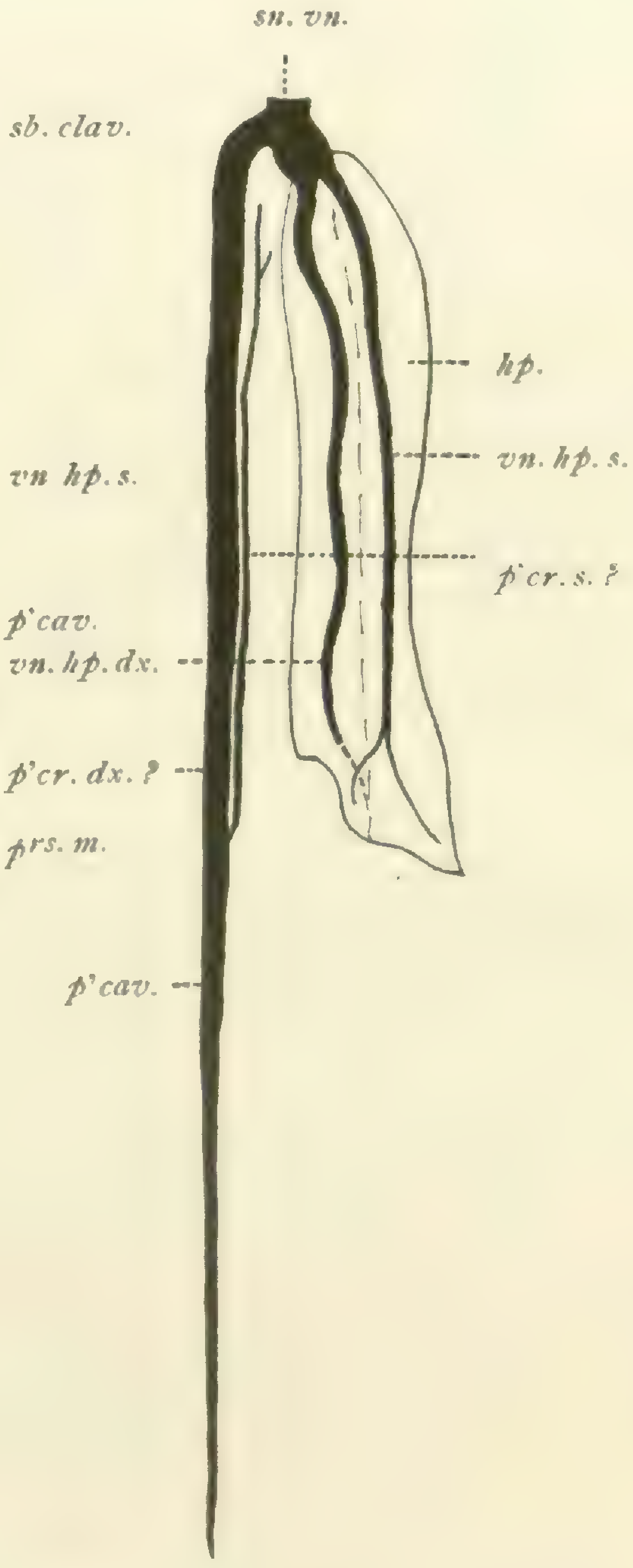

FIG. 2.

The figures represent the central portion of the venous system of *Necturus maculatus* seen from the ventral side and are about one half natural size. The liver is shown displaced slightly to the left of the median plane. Fig. 1 represents the normal condition, the veins within the liver being indicated by broken lines. In Fig. 2 the attachment of the suspensory ligament is indicated by a broken line. *dt. Cuv.*, duct of Cuvier; *hp.*, liver; *jug.*, jugular vein; *p'cav.*, postcava; *p'cr. dx.*, right posterior cardinal vein; *p'cr. s.*, left posterior cardinal vein; *prs. m.*, "Mittelstück" of postcava; *sb. clav.*, subclavian vein; *sn. vn.*, venous sinus; *vn. hp. dx.*, right hepatic vein; *vn. hp. s.*, left hepatic vein.

where it leaves the aorta, and they pass anteriad to terminate in the corresponding ducts of Cuvier, close to the venous sinus. The cardinals may arise from the postcava either separately or by a short common trunk. According to Miller (:00), the latter condition is the more usual. Posteriorly the cardinals anastomose with the renal portals, which have been omitted from the figure as not bearing upon the abnormalities here considered. The hepatic veins are variable in number, size, and termination; but Miller finds that two are larger and more constant than the others. One joins the postcava near the center, the other at the anterior end, of the liver. It is to be noted that in *Salamandra maculosa* there is normally but one large hepatic vein, which is in the left half of the liver (Hochstetter).

In the abnormal case (Fig. 2) the postcava arose normally between the kidneys, but instead of entering the liver, it became continuous anteriorly with a large and apparently median vessel which passed directly anteriad along the dorsal body wall to the heart, without receiving any hepatic veins. The end toward the heart lay somewhat to the right of the median plane and entered the venous sinus from the right side. The hepatics were two very large symmetrical veins, superficial on the ventral side of the liver for their entire length, one on each side of the suspensory ligament. They united at the anterior end of the liver to form a short, bulbous trunk, the anterior end of which was directly continuous with the venous sinus. The left hepatic vein was fairly straight and arose from the posterior end of the liver, where it received a small superficial tributary from the right side of the posterior border. The right one, of about the same size, was more irregular in its course. Its beginning was imbedded in the substance of the liver on the right side of its posterior extremity. Both received small hepatic branches within the liver, as was shown by sectioning.

About one centimeter posterior to the venous sinus and to the left of the median plane, there arose from the body wall a small vein formed by the union of two short branches. In its course posteriad it gradually approached the large median vein described above and passed along its dorsal surface, to which it was intimately attached. Its size increased slightly as it passed

posteriad. By careful dissection it was separated to a point opposite the posterior extremity of the liver. Here it was unintentionally severed from the postcava at what is believed to have been its point of entrance, as it could not be traced any farther. Its junction with the postcava could not be determined positively on account of its small size, the injury to the delicate wall of the postcava, and the exudation of the injected starch mass. The identity of this vessel is open to question, but from its relations and course, and by analogy with the somewhat similar cases mentioned above, it was most probably the atrophied left posterior cardinal corresponding to the very much hypertrophied right posterior cardinal, which was functioning as the anterior part of the postcava.

No further abnormalities were observed in either the circulatory or other systems.

Comparing this case with the normal venous system and considering the development of the postcava, it is inferred that *the right hepatic vein* (*or at least the anterior part of it*) *represents the anterior part of the normal postcava, the normal* "*Mittelstück*" *of the postcava having failed to develop.* Wiedersheim ('98, p. 371), speaking of the development of the postcava in Amphibia, says: "Der vordere (Leber) Abschnitt entstammt offenbar zum Theil der rechten V. omphalo-mesenterica, zum Theil aber entsteht er unabhängig." Hochstetter ('88) states concerning the development of the postcava in Salamandra: "Das Wesentliche an der Hohlvenenbildung ist demnach die Verbindung zwischen Lebervenen und Cardinalvenen und die Verschmelzung der Cardinalvenen in ihrem Urnierenabschnitte" (p. 167); . . . . "diese Verschmelzung erfolgt übrigens erst ziemlich spät, nachdem der sich ganz selbständig entwickelnde Abschnitt der vorderen Hohlvene sich mit der rechten Cardinalvene in Verbindung gesetzt hat . . . ." (p. 163). "Ausnahmsweise kommt es manchmal vor, dass die Entwicklung eines vorderen Hohlvenenabschnittes vollständig ausbleibt, dann bildet sich entweder die rechte oder linke Cardinalvene weiter aus und führt im erwachsenen Thiere das Blut der Nieren, Geschlechtsorgane und des Rumpfes dem Herzen zu" (p. 164).

In comparison with the abnormal cases previously described,

this case of Necturus possesses in the hypertrophied right posterior cardinal, the characteristics of one of Hochstetter's, and in the two large symmetrical hepatic veins, those of one of Joseph's, although, upon the whole, it is strikingly different from both.

BIBLIOGRAPHY.

HOCHSTETTER, F.

'88. Beiträge zur vergleichenden Anatomie und Entwicklungsgeschichte des Venensystems der Amphibien und Fische. *Morph. Jahrb.*, Bd. 13, pp. 119–172, Taf. II–IV, 7 Textfig.

JOSEPH, H.

:01. Ueber zwei Abnormitäten im Venensystem von Salamandra maculosa Laur. *Anat. Anz.*, Bd. 20, pp. 283–293, 4 text figs.

MCCLURE, C. F. W.

:00. On the Frequency of Abnormalities in Connection with the Postcaval Vein and its Tributaries in the Domestic Cat (*Felis domestica*). *Amer. Nat.*, vol. 34, pp. 185–198, 9 text figs.

MCCLURE, C. F. W.

:00a. The Variations of the Venous System in *Didelphys virginiana*. *Anat. Anz.*, Bd. 18, pp. 441–460, 21 Text figs.

MILLER, W. S.

:00. The Vascular System of *Necturus maculatus*. *Bull. Univ. Wisconsin* (*Sci. Series*), no. 33, pp. 211–226, pls. 9–11.

SLONAKER, J. R.

:00. A Strange Abnormality in the Circulatory System of the Common Rabbit (*Lepus sylvaticus*). *Amer. Nat.*, vol. 34, pp. 639–640, 1 fig.

WIEDERSHEIM, R.

'98. Grundniss der vergleichenden Anatomie der Wirbelthiere. 4te, Aufl., Jena, xxiii + 559 pp.

SIR CHARLES BLAGDEN, EARLIEST OF RHODE ISLAND ORNITHOLOGISTS.

REGINALD HEBER HOWE, JUNIOR.

I WAS interested, when compiling the Rhode Island, Massachusetts, and Vermont State lists, to notice the date of the first authentic record for any bird within the States named. The earliest Massachusetts record was of the Black Skimmer (*Rhynchops nigra*) recorded in 1605 in the *Voyages of Samuel de Champlain*. The Vermont list contains accounts of observations made in 1794, by Samuel Williams, while the Rhode Island list dates from the writings of Edward A. Samuels in 1867. The ornithological literature of the State of Maine dates from the *History* of that State by William D. Williamson, published in 1832; that of New Hampshire from the work of Jeremy Belknap in 1792; and that of Connecticut from early in the nineteenth century. That Rhode Island has always been neglected is evidenced by the minimum of literature and the lack of material from the State, in all the collections of the country.

Through the kindness of Mr. William Brewster, I have lately received a copy of the *Bulletin of the New York Public Library* (vol. 7, no. 11, Nov., 1903, pp. 407–446), containing a number of letters from Sir Charles Blagden to Sir Joseph Banks, written from 1776–1780.

Sir Charles Blagden, physician, was born on April 17, 1748. He graduated from the University of Edinburgh, and entered the army as a medical officer, remaining in service until 1814. During the Revolution he was stationed at Charleston, Reedy Island, Delaware, New York, and Newport. He was on intimate terms with Cavendish, the famous chemist, who bequeathed him £16,000. He was also a friend, for fifty years, of Sir Joseph Banks, president of the Royal Society, and he himself was elected secretary of this Society in 1784. He has been described as a "careful worker in physical research," and Dr.

Samuel Johnson, according to Boswell, called him "a delightful fellow." In 1789, he was elected a correspondent of the Académie des Sciences of Paris. On March 26, 1820, he died at Arcueil, Paris, at the home of his friend Berthollet, the renowned chemist.

Sir Joseph Banks was born on February 13, 1743. He attended Harrow and Eton where he was early interested in botany. He afterwards entered Christ College, Oxford, where he became interested in general natural history. From 1768 until 1771, he fitted out and accompanied Cook's expedition on board the "*Endeavor*." He died at Isleworth, June 19, 1820, and his collections and herbarium were finally placed in the British Museum, where it is not improbable some of the Rhode Island animals collected by Blagden, were sent.

One of the letters under date of October 28, 1777, states that the specimens were sent to Europe on "the Brigantine Betsy, a Navy Victualer" in "twelve Kegs" "preserved in Rum" and Blagden writes: "Upon my appointment to the employment which brought me hither, Mr. Barrington desired that I would collect what things fell in my way for the use of his friend Mr. Lever. After considering as maturely as I could what would best answer everybody's purpose, I thought that desiring you & Mr. Barrington to accept the collection jointly between you, would be the properest step. Mr. Lever[1] wants anything that he happens not to have in his Museum, whether it tends to illustrate Science or not; on the contrary nothing can be an object to you but what will conduce to the improvement of Natural History as a branch of Philosophy. . . . All my apprehensions are, lest the coolness which has subsisted between you & Mr. B. should make this division unpleasant; but if it be possible, wave that on the present occasion out of your friendship to me; if it be not possible, the last resource is, that you will each be so kind as to take six kegs apiece: At the same time consider, that at least 19 out of 20 of the things sent must be mere

[1] Sir Ashton Lever "expended an immense fortune in the formation of . . . . the Leverian Museum" near Manchester, which later was removed to London, and was finally sold "by way of lottery" in 1785, to a Mr. Parkinson, who sold it by auction in 1805.

trumpery, fit only to be thrown upon the dunghill; for I took all that offered." Under date of March 2, 1778, Philadelphia, he again writes: "With respect to the Kegs from Rhode-Island, I should deem myself extremely unfortunate if they occasioned the least misunderstanding between you & Mr. Barrington, more especially as I am convinced that they scarcely contain anything worthy your attention; it would be extremely easy to divide them by your taking six apiece; but as Mr. Barrington had previously acquainted me with his intention of sending all that he should receive to Mr. Lever, I thought it would best answer both his purpose and yours, that he should give up to you every thing that was nondescript, (if there be any such) on condition of keeping all the remainder, among which there might be many specimens not yet in Mr. Lever's Museum, & therefore interesting to him though not to you."

Two of the letters — the first dated September 12, 1778, the second undated — contain an annotated list of animals collected in Rhode Island, which were sent home, evidently, by Sir Charles Blagden to Sir Joseph Banks in Europe. The number and sex of the specimens were curiously designated in the following manner: "A string is tied to some part of the animal with its two ends of a length suited to the number to be expressed; every *single* knot on either or both of these ends stands for a unit; every *double* knot, that is, two single knots close together, stands for 10; and a *loop* at one end of the string means 100. .... Where I got a male & female the knotted string was tied to the right leg of the former & to the left leg of the latter."

The birds, which are the subject of this paper, were collected in Rhode Island, and most of them are to be positively identified from the names and descriptive notes. Many of the vernacular names he used are still in use in the State as local cognomens of species; *e. g.*, wamp, for the Eider (*Somateria dresseri*).

Under date of April 10, 1779, New York, he again writes that a Captain Davies "seems to have got every thing" in this country "that was brought to me in Rhode Island, except the Scapog-bird mentioned in my catalogue, which, I believe, he never saw."

Of the seventy-nine birds listed, the following species, I conclude, are almost unmistakably indicated by Sir Charles Blagden. Only the notes as to their comparative abundance are given.

LIST.

1. "No. 2," "Diver" or "Loon" = *Gavia lumme*; "Feb. 18."

2. "No. 3," "Sparrow-Hawk" or "Pigeon-Hawk" = *Falco sparverius* probably, from date of capture. "Feb. 20."

3. "No. 4," "yellow-Bird" = *Astragalinus tristis*. "Feb. 24," also "Apr. 15"?

4. "No. 5," "Blue-Bird" = *Sialia sialis*. "Mar. 15."

5. "No. 6," "No. 42," and "No. 94," "Red-winged Blackbird" = *Agelaius phœniceus*; "male . . . . appeared here the 10th or 12th of March: in a fortnight or three weeks came the females."

6. "No. 7," "Robin" = *Merula migratoria*; "arrive . . . . about the middle of March, & in such quantities & so tame, that a dozen could be shot in an hour within two miles of the town."

7. "No. 8," "yellow Woodpecker" = *Colaptes auratus luteus*. "Mar. 19."

8. "No. 9," "Hildee" = *Oxyechus vociferus*. "March 24."

9. "No. 10," "Snipe" = *Gallinago delicata*. "Mar. 24."

10. "No. 12," "Wamp" = *Somateria dresseri*. "Mar. 25" and "Ap. 9."

11. "No. 13," "Red-billed Coot" = *Oidemia americana*. "Mar. 25."

12. "No. 14," and "No. 15"? "Beach-Bird, or Snipe Beach-Bird" = *Calidris arenaria*. "Mar. 25."

13. "No. 16," "Marsh-Quail" = *Sturnella magna*. "Ap. 1."

14. "Great Loon" = *Gavia imber*; one was shot "April the 5."

15. "No. 17" and "No. 28," "Bald-pated Coot" = *Oidemia perspicillata*. "Ap. 3."

16. "No. 18" and "No. 23," "Old Wife" = *Harelda hyemalis*. "Ap. 3" and "Ap. 8."

17. "No. 19," "Sheldrake" = *Merganser serrator.* "Very plenty." "Ap. 3."

18. "No. 22," "Parrot-Bill," "Noddy" or "Murr" = *Alca torda*; "a rare bird here." "Ap. 10."

19. "No. 24," "Dipper" = *Erismatura jamaicensis*; "very common." "Ap. 8."

20. "No. 25," "Loon" = *Colymbus auritus.* "Ap. 8."

21. "No. 27," "Brant" = *Branta bernicla.* "In Spring, with a southerly wind, prodigious flocks pass close to Sachawest point." "Ap. 13."

22. "No. 29," "White-wing" = *Oidemia deglandi.* "Ap. 13."

23. "No. 30," "Crow Black-bird" = *Quiscalus quiscula + aeneus.* "April."

24. "No. 33," "Cormorant" = *Phalacrocorax auritus* or *carbo*, perhaps both. "Harbour in large quantities on a rock about 2 miles from Sachawest Point, thence called Cormorant Rock." "Ap. 22."

25. "No. 35," "Common Swallow" = *Hirundo erythrogaster.* "Ap. 23."

26. "No. 37," "Pewit" = *Actitis macularia.*

27. "No. 40," "Grass-Plover" = *Bartramia longicauda.* Perhaps *Charadrius dominicus*? "They come in great numbers & are very tame at first, but grow extremely shy & and hard to shoot in a few days. Ap. 29."

28. "No. 43," "Woodcock" = *Philohela minor*; "there are Woodcock's nests in woods of most of the Islands round Rhode Island." "May 6."

29. "No. 46," "black-breasted Plover" = *Squatarola squatarola.* "Lately migrated to the Island; in flocks. May 9." "May 16."

30. "No. 47," and "No. 61," "Tell-tale Plover," "yellow-legged Plover" = *Totanus melanoleucus.* "May 11" and "May 15."

31. "No. 48," "Ox-eye" = *Ereunetes pusillus* "begins to come in large flocks to the ponds near the beach May 11."

32. "No. 49," "ring-necked Plover" = *Ægialitis semipalmata.* "May 11."

33. "No. 50," "King-bird" = *Tyrannus tyrannus*. "May 12."

34. "No. 51," "Quongquéedle" = *Dolichonyx oryzivorus*. "The males appear some time before the females, — which then appear all of a sudden & pair immediately." "May 13."

35. "No. 54," "common Chipbird" = *Spizella socialis*. "Frequenting the gardens April 23d."

36. "No. 55" and "62," and "67," "Rock-Plover," "red-legged Plover," "Whale-Bird" = *Arenaria interpres*. "May 13." "May 15." "May 16."

37. "No. 57," = *Empidonax minimus*. "Frequent in gardens. May 13 & 16."

38. "No. 58," "Thrasher or Thrush" = *Toxostoma rufum*. "Pretty common." "May 13."

39. "63," "Mosquito Gull" = *Sterna antillarum*; "very frequent about ponds near the beaches." "May 15" (see text following "No. 102"). "July the 2d I shot a Mosquito Gull No. 63 with the Minow No. 45 in its mouth, which it was taking to the young. then hid in the sand near the beach."

40. "64," "Humming-Bird" = *Trochilus colubris*. "May 15."

41. "68," "common wild goose" = *Branta canadensis*.

42. "69," "Night-Hawk" = *Chordeiles virginianus*; "very common." "May 16."

43. "No. 70," "Wren" = *Troglodytes aëdon*; "found about shrubs in gardens." "May 16."

44. "72," "Cat-bird" = *Galeoscoptes carolinensis*. "May 17."

45. "No. 73," "Fool Plover" = *Macrorhamphus griseus*. Fool Plover is to-day a local name for this species. "May 20."

46. "75" and "No. 96," "Shike-poke" or "Quawk" = *Nycticorax nycticorax nævius*. "May 22" and "June 19." Perhaps the former name refers to *Butorides virescens*, but it is universally called in the State "Fly-up-the-creek."

47. "76," "Mackarel Gull" = *Sterna hirundo*. "May 24."

48. "80," "red-headed Woodpecker" = *Melanerpes erythrocephalus*. Perhaps *Sphyrapicus varius*. "June 1."

49. "82," "common crow" = *Corvus brachyrhynchos*.

50. "No. 87," "American Cuckoo" = *Coccyzus erythrophthalmus*; probably, because the more common. "June 15."

51. "No. 90," "Tree Heron" = *Nyctanassa violacea*; "very rare." "June 15."

52. "No. 91," "Chimney Swallow" = *Chætura pelagica*; "more common in the inland parts than near the seacoast." "June 15."

53. "No. 92," "Fulica Chloropus" = *Gallinula galeata*; "very rare." "Jun. 16."

54. "No. 93," "Whistling Quail" = *Colinus virginianus*; "common." "Found all the year."

55. "No. 97," "Bank Swallow" = *Riparia riparia*. "June 19."

56. "No. 103," "Whipperwill" = *Antrostomus vociferus*. "Jul. 3."

57. "No. 105," "wild Pidgeon" = *Ectopistes migratorius*. "Jul. 7." Evidently about June 19 "some flights . . . . came over the Island, but the great flocks are not found nearer the sea than Providence."

58. "No. 107," "Gull," "*Sterna nigra*" = *Hydrochelidon nigra surinamensis*. "Jul. 14.".

59. "No. 108," "Kingfisher" = *Ceryle alcyon*. "July 14."

60. "Broad-bill" = *Aythya marila*.

Of Doubtful Recognition.

1. "No. 1," "Common Sparrow" = *Spizella monticola* or *Melospiza cinerea melodia*. "Feb. 18."

2. "No. 12," "Whi[s]tling Diver" = *Clangula clangula americana*?; "coarse species of the Sea Wild Duck, very common. Mar. 25."

3. "wood-pecker" or "Picus hirundo" = *Dryobates pubescens medianus*? Seen "April the 8th."

4. "No. 26," "Loon" or "Colymbus Immer" = *Gavia lumme*? "Ap. 13." "Weighed three pounds."

5. "No. 32," "wood-pecker" = ? "Ap. 17."

6. "No. 34," "Ground Sparrow" = *Spizella pusilla*? "Ap. 23." "Chirps, cannot sing." It is interesting to note that Wilson did not know the Field Sparrow's song.

7. "No. 36," "common Swallow" = *Iridoprocne bicolor*? "Ap. 23."

8. "No. 52," "Goldfinch" = *Carpodacus purpureus*? "May 13th."

9. "No. 53," "Chip-bird" = ? "May 13."

10. "No. 56," "common Swallow" = *Progne subis*? "April 23."

11. "No. 66," "Grasshopper Gull" = *Larus "canus" argentatus.* "May 16."

12. "No. 65," "Plover" = ? "May 16."

13. "71," "Scapog-Bird" = *Hæmatopus palliatus* or *Rhynchops nigra*? If either of these is the bird mentioned it makes the only record of occurrence in Rhode Island.

14. "No. 77," "Gull" = ? "May 24."

15. "79," "Port Royal Bird" = *Ampelis cedrorum*? "rare." "May 29."

16. "No. 83," "bee-bird" = *Tyrannus tyrannus*? "June 7."

17. "84," "dipdapper" = ? "June 7."

18. "No. 101," "yellow bird" = *Dendroica æstiva*? "June 26."

19. "No. 104," "black snipe" = *Helodromas solitarius*? "Jul. 4."

THE LITERATURE OF EDESTUS.

C. R. EASTMAN.

It has happened not infrequently that discoveries of the most surprising nature in paleontology have been made almost simultaneously in different parts of the world. Hardly has some form of animal life, previously unheard of and apparently unique, been brought to light, when identical or closely related types are reported from remote regions. Familiar coincidences of this nature are recalled by Pareiasaurus amongst reptiles, Helicoprion amongst fishes, and Dæmonhelix amongst problematical fossils.

Although our knowledge of Helicoprion is comparatively recent, a very considerable literature has suddenly sprung into being concerning it and related forms, of which the older-known Edestus and Campodus are the most instructive and important. The latter, in fact, provides the only satisfactory clue we possess regarding the anatomical and systematic position of the whole series of Edestus-like forms.

Without entering into any general discussion, it may be said that the majority of writers concur in the opinion that the "spiral saw" of Helicoprion and the arched segments of Edestus represent stages of that peculiar modification amongst Paleozoic sharks whereby series of teeth become fused and inrolled without being shed. The most recent communication that has appeared on this subject strikes a slightly discordant note, in that the author, Mr. Edwin T. Newton,[1] suggests that Helicoprion and Edestus may not be of the same general nature after all. Although admitting that the former may be very plausibly regarded "as the enrolled dentition at or near the symphysis of an Elasmobranch, possibly allied to Cestracionts," his interpretation of Edestus is that it is a segmented dermal defence, such as a dorsal fin-spine.

[1] Newton, E. T. On the Occurrence of Edestus in the Coal Measures of Britain. *Quart. Journ. Geol. Soc.*, vol. 60, 1904, pp. 1–8, pl. 1.

As has just been observed, a key to the understanding of Edestus-like forms is furnished by the symphysial dentition of Campodus, and there lies at hand a simple and reliable test for demonstrating their common plan of structure. For those who have not actual specimens at command, recourse must be had to plaster casts of Campodus and Edestus, which fortunately are not rare among the larger museums of this country. If one will place side by side the symphysial segments of *Campodus variabilis* and *Edestus heinrichi*, orienting them in natural position with the anterior end foremost, one will be struck by their almost perfect correspondence, part for part, and line for line.

First and most conspicuously, it will be noted that the coronal apices of Campodus and Edestus are similarly formed, their edges being denticulated and sides striated in corresponding manner. It will be seen further that the basal portion of the crown projects forward characteristically in both forms, and that the different segments overlap and are fused with one another in an identical fashion. Only in Edestus is the peculiar trough-like base much produced forwardly, and being composed of vasodentine, is usually well preserved, whereas in Campodus the basal support for the teeth is cartilaginous, and hence unsuited for preservation. But the structural resemblance of all parts is so obvious, especially when one occupies himself with original specimens, that the idea of a homology existing between them cannot be avoided. In fact, the evidence appears conclusive that Campodus, Edestus, and Helicoprion represent successive stages of modification amongst Cestraciont sharks. The importance of these forms from a morphological standpoint is such, and the discussion of them so widespread, that it seems desirable to draw up an index to their special literature, which is given below.

BIBLIOGRAPHY.

VAN DEN BROECK, E.

:03. Ce que doit signifier la spirale de Helicoprion. *Bull. Soc. Belge Géol.*, vol. 13 (for 1899), Procès-verbaux, pp. 215–218.

DEAN, B.

'95. Fishes, Living and Fossil. New York, 8vo, pp. 28–30.

DEAN, B.

'98. On a New Species of Edestus, *E. Lecontei*, from Nevada. *Trans. N. Y. Acad. Sci.*, vol. 16, pp. 61–69, pls. 4–5.

EASTMAN, C. R.

:00. Karpinsky's Genus Helicoprion. *Amer. Naturalist*, vol. 34, pp. 579–582.

EASTMAN, C. R.

:01. On Campodus, Edestus, Helicoprion, etc. *Science*, n. s., vol. 14, p. 795.

EASTMAN, C. R.

:02. On Campyloprion, a New Form of Edestus-like Dentition. *Geol. Mag.*, dec. 4, vol. 9, pp. 148–152, pl. 8.

EASTMAN, C. R.

:02. Some Carboniferous Cestraciont Acanthodian Sharks. *Bull. Mus. Comp. Zoöl.*, vol. 39, pp. 55–99, pl. 1–7.

EASTMAN, C. R.

:02. Genus Campodus de Koninck. *Amer. Naturalist*, vol. 36, pp. 852–854.

EASTMAN, C. R.

:03. Carboniferous Fishes from the Central Western States. *Bull. Mus. Comp. Zoöl.*, vol. 39, pp. 163–226, pl. 1–5.

EASTMAN, C. R.

:03. The Nature of Edestus and Related Forms. *Mark Anniversary Volume*, pp. 279–289, pl. 21.

FUCHS, T.

:00. Ueber die Natur der Edestiden, etc. *Sitzungsber. Akad. Wiss. Wien*, vol. 109, pp. 5–9, pl.

HITCHCOCK, E.

'56. Account of the Discovery of the Fossil Jaw of an Extinct Family of Sharks from the Coal Formation. *Proc. Amer. Assoc. Adv. Sci.* for 1855, pp. 229–230.

HITCHCOCK, FANNY R. M.

'88. On the Homologies of Edestus. *Proc. Amer. Assoc. Adv. Sci.* for 1887, p. 260. Also *Amer. Naturalist*, vol. 21, 1887, pp. 847–848.

JAEKEL, O.

'99. Ueber die Organisation der Petalodonten. *Zeitschr. deutsch. geol. Gesellsch.*, vol. 51, p. 297.

Jaekel, O.

:00. A. Karpinsky: Ueber die Reste von Edestiden, etc. [Review]. *Neues Jahrb. f. Mineral.*, vol. 2, 1900, pp. 144–148.

Jordan, D. S.

:05. A Guide to the Study of Fishes. Vol. 1, p. 529.

Karpinsky, A. P.

'99. Ueber die Reste von Edestiden und die neue Gattung Helicoprion. *Verh. russ.-kais. min. Gesellsch. St. Petersb.*, ser. 2, vol. 36, pp. 361–476, pls. 1–4. Also, *Mém. Acad. Imp. Sci. St. Pétersb.*, ser. 8, vol. 8, pp. 1–76, pls. 1–4.

Karpinsky, A. P.

:03. Ueber neue Literatur und andere Daten betreffend Reste von Helicoprion. *Verh. russ.-kais. min. Gesellsch. St. Petersb.*, ser. 2, vol. 40 (*Protocolle der Sitzungen*), p. 94.

Klaatsch, H.

:01. Zur Deutung von Helicoprion Karp. *Centralbl. f. Mineral.* (1901), pp. 429–436.

Koken, E.

:01. Helicoprion im Productus-Kalk der Salt-Range. *Centralbl. f. Mineral.* (1901), pp. 225–227.

Leidy, J.

'56. Indications of Five Species, with two New Genera of Extinct Fishes. *Proc. Acad. Nat. Sci. Phila.*, vol. 7, 1854–55, p. 414.

Leidy, J.

'57. Remarks on certain Extinct Species of Fishes. *Proc. Acad. Nat. Sci. Phila.*, vol. 8, 1856, p. 301.

Leidy, J.

'58. Descriptions of some Remains of Fishes, etc. *Journ. Acad. Nat. Sci. Phila.*, ser. 2, vol. 3, 1856, pp. 159–165, pl. 15.

Lohest, M.

'83. Recherches sur les poissons des terrains paléozoïques de Belgique. *Ann. Soc. Géol. Belg.*, vol. 11, pp. 295–328.

Newberry, J. S.

'66. In *Geol. Surv. Illinois*, vol. 2, *Palæontology*, p. 84, pl. 4.

Newberry, J. S.

'89. On the Structure and Relations of Edestus, etc. *Ann. N. Y. Acad. Sci.*, vol. 4, 1888, pp. 113–122, pls. 4–6. Also *Monogr. U. S. Geol. Surv.*, vol. 16, 1889, pp. 217–226, pls. 39–40.

Newberry, J. S., and Worthen, A. H.

'70. In *Geol. Surv. Illinois*, vol. 4, p. 350, pl. 1, fig. 2.

Newton, E. T.

:04. On the Occurrence of Edestus in the Coal Measures of Britain. *Quart. Journ. Geol. Soc.*, vol. 60, pp. 1–8, pl. 1. [Followed by discussion by A. S. Woodward.] Also *Geol. Mag.*, dec. 5, vol. 1, p. 40.

OWEN, R.

'61. Palæontology. 2d ed., Edinburgh, 8vo, pp. 123–124, fig. 38.

ST. JOHN, O. H.

:02. [Observations on Edestus and Cochliodus.] *Amer. Naturalist*, vol. 36, pp. 658–59.

ST. JOHN, O. H., AND WORTHEN, A. H.

'75. In *Geol. Surv. Illinois*, vol. 6, pp. 318–323, pl. 8.

SIMOENS, G.

:03. Note sur *Helicoprion bessonowi* Karpinsky. *Bull. Soc. Belge Géol.*, vol. 13, 1899, pp. 235–244.

TRAUTSCHOLD, H.

'79. Die Kalkbrüche von Mjatschkowa. *Nouv. Mém. Soc. Imp. Nat. Moscou*, vol. 14, p. 49, pl. 6, fig. 8.

TRAUTSCHOLD, H.

'84. Ueber Edestus und einige andere Fischreste des moskauer Bergkalke. *Bull. Soc. Imp. Nat. Moscou*, vol. 58, pt. 2, 1883, pp. 160–174, pl. 5.

TRAUTSCHOLD, H.

'86. Ueber das Genus Edestus. *Bull. Soc. Imp. Nat. Moscou*, vol. 61, pt. 2, 1885, p. 94.

TRAUTSCHOLD, H.

'88. Ueber *Edestus protopirata* Trd. *Zeitschr. deutsch. geol. Gesellsch.*, vol. 40, p. 750.

TRAUTSCHOLD, H.

'90. Ueber *Protopirata centrodon* Trd. *Bull. Soc. Imp. Nat. Moscou*, no. 3, pp. 317–321.

VAN DE WIELE, C.

:03. Aperçu sur les vestiges fossiles d'Édestides, etc. *Bull. Soc. Belge Géol.*, vol. 13, 1899, pp. 205–218, 231–234, 244–247.

WOODWARD, A. S.

'91. Catalogue of the Fossil Fishes in the British Museum, pt. 2, pp. 151–154.

WOODWARD, A. S.

:00. Helicoprion — Spine or Tooth? *Geol. Mag.*, dec. 4, vol. 7, pp. 33–36.

WOODWARD, A. S.

:03. Note sur l'Helicoprion et les Édestides. *Bull. Soc. Belge Géol.*, vol. 13, 1899, Procès-verbaux, pp. 230–233.

WOODWARD, H.

'86. On a Remarkable Ichthyodorulite from the Carboniferous Series, etc. *Geol. Mag.*, dec. 3, vol. 3, pp. 1–7, pl. 1.

YABE, H.

:03. On a Fusulina-Limestone with Helicoprion in Japan. *Journ. Geol. Soc. Tokyo*, vol. 10, pp. 1–13, pl. 1–2.

ZITTEL, K. A.

:02. Textbook of Palæontology. English ed., vol. 2, p. 27.

NOTES AND LITERATURE.

ZOÖLOGY.

Guide to the Birds of New England and New York.[1]— This guide to the birds is on the same general plan as a number of recent bird-books, but the effort has been made to adapt it especially to the most elementary beginners. For this purpose it appears to be well fitted, and the author is to be complimented upon his constant appreciation of the limited view-point of the novice in bird study. Brief introductory chapters deal with "The object and plan of this guide," "Birds and their seasons," "Migration," "Distribution," "Hints for field work," and "How to use the keys." The result of intimate experience with beginning field classes is apparent in these hints.

The keys include only "the common land-birds of New England and eastern New York," omitting "the hawks, the owls, the Mourning Dove, and the game-birds." Separate keys are given respectively for winter, for March, for April, for May, for summer, and for autumn, and each of these has under separate divisions those birds which one may expect to find only in the Upper Austral or the Canadian life-zones. These keys are based primarily upon conspicuous coloration and secondarily upon size, supplemented by characteristics of color, habits or habitat. Taken in connection with the fuller descriptions, and often excellent, brief biographies given in the body of the work, they impress one as being very efficient. In the descriptive portion are incorporated the water birds and others not included in the scope of the keys, and one cannot but regret that some guide is not given to aid in their identification as well. The illustrations consist of five full-page plates, including a map showing the life-zones in New England, and ninety-five text figures, which add much to the usefulness of the book.

L. J. C.

Hornaday's American Natural History.[2] — It is perhaps unfor-

[1] Hoffmann, Ralph. *A Guide to the Birds of New England and New York.* Boston and New York, Houghton, Mifflin & Co., 1904. 8vo, xiii + 357 pp.

[2] Hornaday, William T. *The American Natural History. A foundation of useful knowledge of the higher animals of North America.* Illustrated by 227 original drawings by Beard, Rungius, Sawyer, and others. 116 photographs, chiefly by Sanborn, Keller, and Underwood, and numerous charts and maps. Charles Scribner's Sons, New York, 1904. Large 8vo, xxv + 449 pp.

tunate that a work dealing with the vertebrates only should pre-empt such a broad title as "The American Natural History," which, without the accompanying subtitle, is apt to be rather misleading. The latter, "A foundation of useful knowledge of the higher animals of North America," is much more nearly descriptive of the character of the book in hand. As the author states in his preface, it has been his primary intention to provide for the boys and girls of North America between the ages of fourteen or fifteen and the age at which they usually enter the university, an introduction to the "higher animals" of the continent, in a form that will be interesting and pleasing as well as instructive; also to furnish a book of reference for teachers in the intermediate grades. All who have read Mr. Hornaday's "Two Years in the Jungle" are aware of his ability to write entertainingly, and his years of experience in the field and in the New York Zoölogical Park have given him opportunities for studying the living animals such as comparatively few men have had. These advantages have been combined to make "The American Natural History" good and instructive reading, not only for young people, but for any who have a limited acquaintance with our animals.

In general, only the commoner forms have been selected for treatment, but in some cases descriptions are given of the rarer species, while a number of exotic animals, such as the Monotremes, the fruit-eating bats, etc., are introduced to fill the gaps in the North American fauna. The treatment of the various forms varies considerably, apparently to a large extent with the author's interest. The portion dealing with the Ungulates is especially extensive and contains much original information gained from experience with the animals in captivity. Throughout the work a special point has been made of refuting popular fallacies, such as, that beavers use their tails as trowels, that porcupines shoot their quills, that mountain sheep alight on their horns, and that the hog-nosed snake is poisonous, — a feature which should be conducive of good results. Protection, especially of the game animals, has also received considerable attention and emphasis, a subject which it is well to bring to the attention of the public whenever possible.

The illustrations are numerous, and in most cases excellent. This is especially true of the reproductions of photographs, which cannot be praised too highly; but on the other hand, some of the drawings, especially of the mammals and fishes, seem hardly up to the standard of the day, at least in artistic effect. One cannot but wish that in

some cases the backgrounds had been omitted entirely, as in the figure of the sawfish (p. 435), the chimera (p. 431), and others. It is a question, too, whether the painting-in of other backgrounds in photographs is legitimate in a book of this nature, and whether it is not apt to be misleading to beginners when no explanation is given. One might imagine, for example, that the puma (p. 20) is a docile beast which poses calmly in its mountain home in order to be photographed; see also the polar bear (p. 36), the flamingo (p. 266), etc. The "landscape charts" used to illustrate relationships and habitat seem rather strained and overdrawn, while these and the text are somewhat misleading in constantly referring to animals as "higher" and "lower," tending to give the student an idea that the vertebrate affinities lie in a direct chain, rather than forming a complicated, branching system.

Mistakes of fact are by no means lacking, especially points in the anatomy of the exotic species; and the classification is throughout largely artificial and based upon superficial resemblances and analogies.

In the introduction the author makes some very conservative remarks regarding the tendency to humanize animals and to ascribe to them a higher order of intelligence than they possess; but unfortunately he has in many cases been unable to avoid at least the semblance of the fault himself, as when he says (p. 93): "*The most humorous of all rat-like animals* is the Trading Rat, ... which delights in playing practical jokes upon its human neighbors." He is perhaps inclined at times, too, to make over-positive statements which cannot be taken quite literally.

This book will probably not become generally used as an intermediate text-book; but it will be found a partial substitute for those who have no opportunity to visit a good zoölogical park, and will certainly add greatly to the pleasure of those who do have that privilege. It is an excellent work for home reading and reference.

L. J. C.

Notes. — The zoögeographical relations of South America recently have been discussed by Dr. G. Pfeffer (*Zoöl. Jahrb.*, Suppl. 8, 1905, pp. 407–442), with reference to the reptiles, amphibians, and fishes, especially as to the question of the former land connections of this continent with Africa and with Australia. It is apparently the desire of the author to demonstrate that there is no evidence whatever for the assumption of such connections, and, consequently, the paper

chiefly discusses those cases, which are not in favor of the former land connection between these continents, that is to say, which do not directly bear upon this question, while other cases, which might possibly furnish additional evidence are dismissed shortly.

The general trend of Pfeffer's argumentation is as follows. There are a number of instances, where discontinuous distribution in all or some of the southern continents is evidently a remnant of a former universal or subuniversal distribution, which is clearly shown by the presence of fossil remains of the several groups of animals in other parts of the world. On the other hand, there are similar cases, in which fossil remains are not known at all, or are not known from the northern continents. Here, Pfeffer claims, we have the right to assume, that these groups nevertheless once existed on the northern hemisphere, and they also once were subuniversal in their distribution.

Here we are again confronted with a fallacious generalization of correct observations, a way of drawing conclusions that has so often given origin to incorrect general theories. Of course, if some groups of animals, that are now more or less restricted, were once universal in their distribution, it is evident, that very likely some others were, of which no direct evidence of universality has been found. But the conclusion, that all such cases are to be explained by this assumption, is, to say the least, a little rash. Moreover, we do not intend to find a theory that might under certain assumptions explain the present facts, but we ought to try to find the correct explanation, and thus no way of ascertaining the latter should be neglected, and doubtful cases should not be dismissed shortly. but subjected to a careful and thorough study.

In the present paper, Pfeffer only talks of paleontological evidence, and almost entirely neglects the morphological (systematic) relations of the different forms. It is sufficient for him, if certain forms are found in Africa and South America, to point out that they might have been once present also in North America and Eurasia, and that thus a connection may be established (over Bering Sea). If similar forms are also found in India, this assumption seems to him beyond question. He does not pay the slightest attention to the mutual relations of these forms.

Now it is a fact, that the former land connections between tropical South America and Africa, and between southern South Africa and Australia have been supported chiefly by studies of the degree of the relation of their faunas. We know cases where members of the

fauna of South America find allied forms in many parts of the world, but where the most closely allied forms are found in Australia; in other cases, the nearest relations are found in West Africa. For such cases the theory of former subuniversal distribution is entirely insufficient, and only leads to the further question, why it is, that from a former universal distribution, the most closely allied remnants are found in the most remote parts? For we must always bear in mind, that, if we do not admit direct connections between South America and Africa, and South America and Australia, the connection of these parts always goes by way of Bering Sea or Greenland.

Pfeffer himself mentions a number of instances, where the present distribution appears to favor a direct connection of the three southern continents, but he never studies them closely, and is satisfied with the conclusion that they very likely are also remnants of a former subuniversal distribution. The following are the most striking examples: *Chelonia*, family Miolaniidæ; *Lacertilia*, genus Mabuia, family Amphisbænidæ; *Ophidia*, families Typhlopidæ and Glauconiidæ, genus Leptodira; *Batrachia Anura*, families Pipidæ, Cystignathidæ, Hylidæ, and Engystomidæ; *Batrachia Apoda*, family Cœciliidæ; *Teleostei*, families Characinidæ, Symbranchidæ, Serranidæ, Cichlidæ.

I do not say that these groups actually furnish evidence for the supposed former connections of the southern continents; I only want to call attention to them, with a view to having them made the object of careful, detailed, and unprejudiced examination, paying principal attention to the mutual affinities of their representative members in the different parts of the world. Pfeffer has not done this, and thus his treatment of these groups is superficial and unsatisfactory; in some of the above instances, objections to the assumption of former subuniversality of distribution are evident at the first glance.

Thus Pfeffer's final conclusion, that there is no necessity for the assumption of direct land connections between South America and Africa, and South America and Australia, upon zoögeographical grounds, is not properly supported even with reference to those groups which he made his special object of study in the present paper. In the face of the fact that there are other groups not mentioned and studied by Pfeffer, that have furnished positive evidence for these connections, and in which the assumption of former subuniversal distribution is entirely unsatisfactory, rendering the present conditions only more unintelligible, we get the impression that Pfeffer did not take up these studies with an unbiased mind.

One additional objection should be made. Pfeffer repeatedly talks of a pre-Tertiary South America, and of the separation of South America from the rest of the world at the end of the Cretaceous time (p. 411, p. 427, p. 430; "præpanamensisches Pan-America"). This tends to show that his ideas about the geological history of South America are entirely at variance with certain geological facts. We know that there was no South America at all as a continuous mass before the beginning of the Tertiary, and that the first connection of what is now South America with North America falls into the Miocene. For this we do not possess a mere theory, but positive geological facts; it is impossible to deny the existence of Jurassic and Cretaceous marine deposits over large parts of South America, or to neglect the fact of their existence. But if we pay due attention to this, then it is inadmissible to speak of a pre-Tertiary South America, and to talk of a severing-off of South America from the rest of the world at the end of the Cretaceous.

A. E. ORTMANN.

A detailed account of the anatomy of the chiton, *Cryptoplax larvæformis*, has been published by E. Wettstein (*Jena. Zeitschr.*, Bd. 38, p. 473).

N. Maclaren (*Jena. Zeitschr.*, Bd. 38, p. 573) discusses the structure and systematic relations of two trematodes, *Diplectanum æquans* Wagener and *Nemathobothrium molæ* n. sp.

Anatomy and Histology of Dentalium. — The following facts are recorded by M. Boissevain (*Jena. Zeitschr.*, Bd. 38, p. 553) on the anatomy and histology of Dentalium. The whole foot is ciliated and glandular. The intestinal musculature consists of a thin layer of circular fibers with occasional muscle bridges. The subradular organ carries an organ of taste. The communication between the genital glands and the kidney is renewed with each period of sexual activity.

F. A. Bather, in the *Geological Magazine* (dec. 5, vol. 2, p. 161) characterizes *Sympterura minveri*, n. g. et sp., a Devonian Ophiurid from Cornwall. The genus is thus diagnosed: a Lapworthurid with spinulose disc extending to second arm-segment, with oral skeleton of teeth, long jaws, and short mouth-frames (torus not seen), with free arm-segments containing a vertebral ossicle, possibly compound, grooved ventrally and provided on each side with two wings, to the distal of which is attached an adambulacral spiniferous element. The structure of the arm-segments suggests

that the vertebræ may be composed of two successive pairs of ambulacral elements, and reasons are given for suspecting that this may be the case in all the more advanced Ophiurids. The holotype of the species, which is the first echinoderm described from these Cornish slates, is in the British Museum.

In recent numbers of the *Bulletin du Musée Océanographique de Monaco*, E. Chevreux describes two new deep-sea amphipods, *Cyphocaris alicei* and *C. richardi*, from the waters between the Canaries and the Azores. G. O. Sars contributes the first part of a preliminary list of the Calanoids collected during the Prince of Monaco's deep-sea explorations. A list of the Symphyla and Diplopoda of the principality of Monaco is given by H. W. Brölemann.

The migratory movements of certain species of Pierids in the Amazon valley are described by Dr. Gœldi in vol. 4 of *Boletim do Museu Gœldi*. The same journal contains a list of the Brasilian birds described by Spix, Wied, Burmeister, and Pelzeln, and a catalogue of the mammals in the collection of the Para Museum. A number of interesting notes on the mammals are added and well executed plates illustrate several of the species.

(*No. 461 was issued May 6, 1905*).

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THE AMERICAN NATURALIST

A MONTHLY JOURNAL
DEVOTED TO THE NATURAL SCIENCES
IN THEIR WIDEST SENSE

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THE

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RESTORATION OF THE TITANOTHERE MEGACEROPS.

RICHARD S. LULL.

In a recent study of a fine specimen of Megacerops discovered in the Bad Lands of South Dakota by an expedition from Amherst College, the author was impressed by several features which suggested a somewhat radical departure from the generally accepted restorations of these remarkable animals. The accompanying photograph from a model by the author aims to express his conception of the creature in the flesh.

The Amherst specimen was found in the Titanothere (White River) Beds about thirty-five feet above their base, in a place where practically all of the one hundred and eighty feet of the deposits were exposed. Hence it is reasonable to suppose that the remains represent a species not very primitive, nor yet showing the extreme of specialization exhibited by later forms, in other words a fairly typical titanothere.

The creature was of adult stature, though the vertebral epiphyses had not coössified with their centra; but, as Marsh has shown, this feature, which one also finds in the elephants, implies the late maturity which is correlated with huge size.

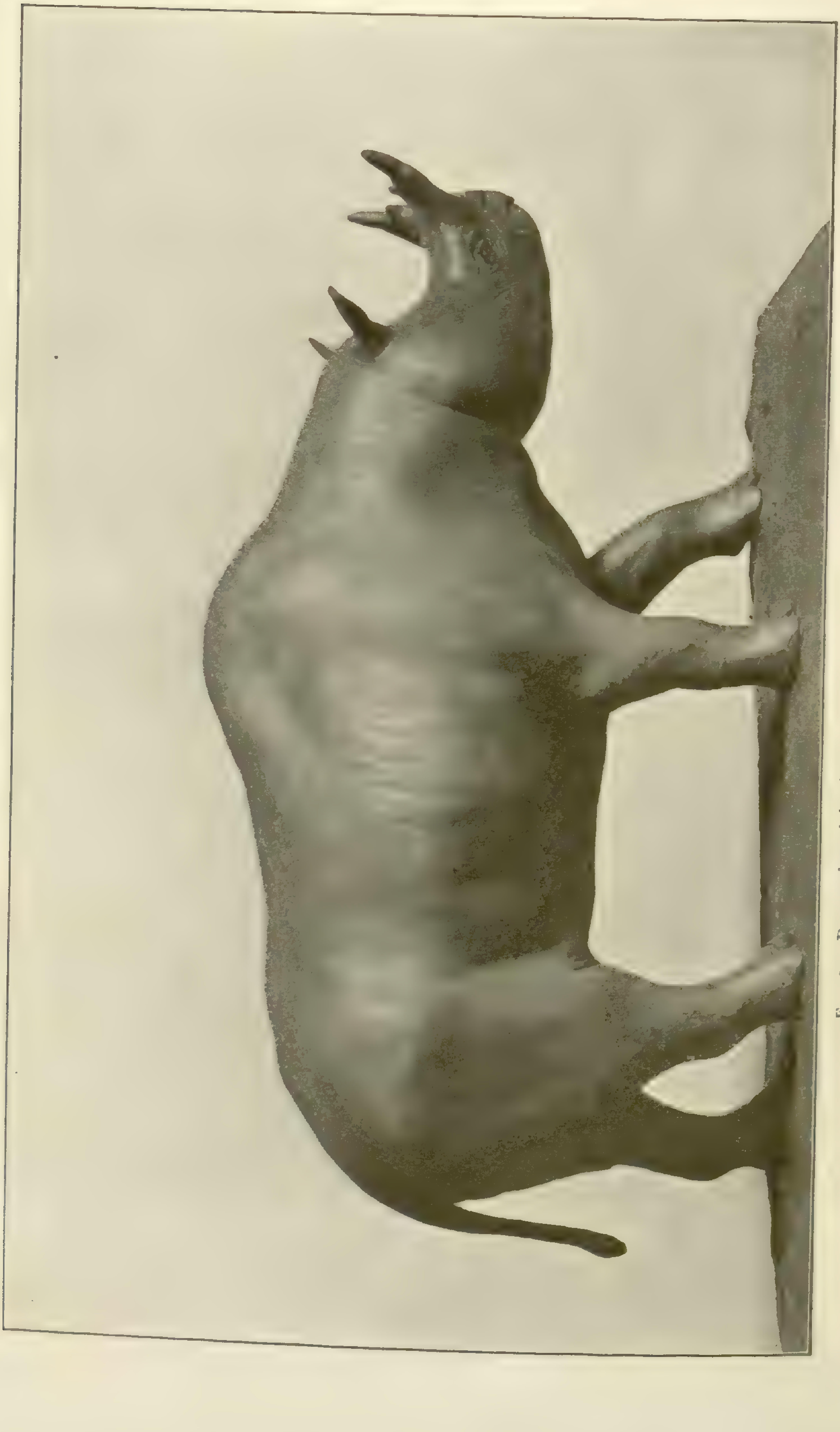


Fig. 1.— Restoration of the titanothere Megacerops, from a model by the author.

The full dentition had been acquired, the teeth being somewhat worn, which would seem to indicate an animal in its prime. The titanothere measured about seven feet four inches in height to the withers and a little more than twelve feet in length. Its weight was probably between one and a half and two tons.

The general proportions suggest the rhinoceros, though, while remarkably specialized as to dentition and the armament of the head, in other respects the titanothere is more primitive than any other perissodactyl, notably in the shorter back and in the structure of the fore foot.

The limbs are stouter than in the rhinoceros, especially at the wrist and ankle, and the degree of angulation between the various segments is less, probably to withstand the greater bodily weight. The fore limb is remarkably robust, and the great roughenings on the various bones, notably the humerus and the olecranon process at the elbow imply enormous muscular power. The fore foot is four-toed and symmetrical, with the main axis lying between the third and fourth digits as in artiodactyls. The retention of the outer digit would seem to imply that the great weight of the head and shoulders necessitated strength rather than a modification for speed. In the extremely flexible though strong wrist and the immense olecranon process one sees indications of a supple limb, a compromise between the pillar-like supporting limb of the elephant and one which would give its owner more agility in lying down or rising, or in charging its enemy.

The hind limb departs from the rhinoceros type mainly in the straightness of the upper segment whose bone, the femur, is long, without a conspicuous third trochanter, and with its shaft flattened fore and aft in such a manner as to imply that the strain brought to bear upon it during life was in the direction of its length. While the calcaneum is rather prominent, the limb must have been but little flexed at the ankle and almost straight when viewed from the rear; decidedly more elephantine than rhinoceros-like in general aspect.

The most notable feature of the trunk, aside from its relative shortness, is the great height of shoulder resulting from the elongated spines of the anterior dorsal vertebræ, which have well roughened extremities for the attachment of the liga-

mentum nuchæ and the huge muscles which supported the skull. Neither the rhinoceroses nor the elephants exhibit such a development as this and one is reminded irresistibly of the bisons in which the head becomes an offensive weapon of great power. Certainly this development implies more than the mere passive support of the head and is probably directly correlated with the development of the cranial armature.

FIG. 2.— Anterior view of the skull of Megacerops, from a specimen in the Amherst College Museum.

Rhinoceroses charge their enemies, using the nasal horn with good effect, and here again there seems to be a direct relationship between the height and power of the shoulders and the degree of development of the horns. In the rhinoceros, how-

ever, the thrust is a vertical one, while in most titanotheres, notably in the one under consideration, there is evidence of strong lateral as well as vertical motion.

In the genus Symborodon the horn prominences are not connected by a web or bridge of bone as in this genus, Megacerops, which would indicate in the former an absence of lateral stress against the horns as though they were used more as in Rhinoceros. It would be interesting to note whether a comparative study of the skeletons would indicate the development or strengthening of special muscles in forms wherein the lateral stress obtained.

The titanothere skull is one of the most unique and bizarre

FIG. 3.— Head of the Megacerops restoration showing the nasal horns.

among mammals, due to the development of the remarkable nasal prominences which bore the horns and the wide expanse of the zygomatic arch which, in the later types, became a broad shelf-like expansion of bone. The development of the zygomata and the height and breadth of the occiput seem to be directly correlated with the development of the horns, the necessity being to provide leverage for the effective use of these weapons.

In the previous titanothere restorations the nasal prominences are always indicated as sheathed with horn, but a glance at the photograph of the skull will disclose the total absence of vascular impressions such as the horn cores of cattle and of the great

horned dinosaurs (Ceratopsia) always exhibit. Another feature which is indicated in the figure is that the summit of each main prominence as well as those of the lesser secondary ones are curiously rugose resembling, though the rugæ are coarser, the roughened patches beneath the horns of the rhinoceros.

Thus one is led to doubt the probability of a horny sheath covering the entire prominence, yet the very mobility of the neck and the strength of the head-wielding muscles indicate the presence of an efficient armament of a size commensurate with the strength of its support. This together with the rugosities seems to point to the existence of horns formed, as in the rhinoceros, of agglutinated hair-like fibers; a larger pair upon the summits of the main, and, in this species, a lesser pair upon the secondary prominences.

This conception perhaps renders the creature somewhat more grotesque, but it would surely provide him with offensive and defensive weapons which with his evident prowess would make the titanothere peerless among the creatures of his time.

AMHERST, MASS.

SYNOPSES OF NORTH AMERICAN INVERTEBRATES.

XXI. The Nemerteans.

WESLEY R. COE.

Part I.

Species Occurring on the West and Northwest Coasts of North America.[1]

The Nemerteans embrace a highly specialized group of flatworms, the most characteristic features of which are the soft extensible body without indication of external segmentation, the highly developed eversible proboscis, the straight intestine, opening at the posterior end of the body, and the absence of any distinct body cavity.

The body is commonly long, flattened, and ribbon-like (Cerebratulus), filiform (Cephalothrix, Lineus), broad and flat (Drepanophorus), thick and rounded (Euborlasia), or short and cylindrical (Tetrastemma), but in nearly all forms is extremely extensible and may often be contracted to one tenth the length of the fully extended worm. In size there is the greatest variation found in any group of worms, for there are minute species (Tetrastemma) but 5 mm. long and a half millimeter thick when sexually mature, while another (*Lineus longissimus*) may become

[1] Of the 87 species which have thus far been recorded from the west and northwest coasts, only 19 are known to occur on the east coast of North America or in other regions of the globe. Because of this geographical limitation of the species it seems desirable to divide the synopsis of North American Nemerteans into two parts, the first to include those forms which have been collected on the west coast between Panama and the Arctic Ocean, the second to embrace the Atlantic species. This plan seems particularly desirable inasmuch as the diagnostic characters are necessarily based to a considerable extent on anatomical peculiarities, which have been somewhat more fully studied in the Pacific species than in those from the east coast of North America.

25 meters in length when fully extended, but remains as slender as a thread; still another (*Cerebratulus lacteus*) grows to be 7 meters long and 20 mm. wide, while the single known individual of *Euborlasia maxima* was 45 mm. in width after preservation.

Although the body is without external segmentation, many of the internal organs are metamerically arranged. The body is covered throughout with glandular and ciliated epithelium. A true body cavity being wanting, the space between the muscular walls of the body and the intestine is filled with gelatinous tissue, or parenchyma. Many species of the Heteronemertea have a delicate caudal cirrus beneath the anal opening at the posterior end of the body, and the representatives of a single genus (Nectonemertes) are provided with a pair of lateral swimming appendages near the anterior end of the body.

The proboscis is bathed in a corpusculated fluid, enclosed in a special muscular sheath, and opens at the anterior end of the body, sometimes in connection with the mouth and sometimes separately. In many species it is nearly as long as the body itself; it is lined with glandular epithelium, and in certain genera is provided with rhabdites or nematocysts. In one of the four orders (Hoplonemertea) there are highly specialized calcareous stylets of such definite size and shape that they form most convenient and reliable diagnostic features.

The mouth is situated anteriorly, either in front of the brain, as in the Hoplonemertea, or immediately behind it, as in the other two orders. The mouth leads into the esophagus, which is often demarcated from the succeeding portion, the stomach; the latter opens into the intestine, which in most genera is provided with paired lateral diverticula. In the Hoplonemertea the stomach is prolonged into a narrow tube, pylorus, which opens well back of the anterior end of the intestine, the latter thus extending forward beneath the pylorus as the intestinal cæcum. Other appendages occur in certain species.

The blood circulates in two or three longitudinal vessels, which usually have numerous anastomoses and open into one or more large lacunæ in the head.

The excretory organs, or nephridia, usually consist of a pair of lateral canals, the ramifications of which lie in close relation

with the blood vessels in the esophageal region. One or more efferent ducts lead from each main canal to the exterior of the body or, in rare instances, to the esophagus.

The muscular system consists of either two or three strong layers of fibers, the arrangement of which forms a convenient diagnostic character and is described in the key to the orders. In some forms there are additional secondary layers.

The relative position of the principal nerve cords with respect to the muscular layers is likewise of primal importance in classification. The central nervous system consists of a four-lobed brain, the two lobes of each side being closely united with each other and joined to those of the other side by a commissure above and one below the rhynchodæum, and a pair of large lateral nerves, accompanied by ganglion cells, extending from the ventral pair of brain lobes to the posterior end of the body. In addition, a dorso-median nerve is commonly present, and sometimes a ventro-median one; most forms have a pair of well developed esophageal nerves, and nearly all have special proboscis nerves, together with peripheral nerves to the integument, ocelli and other sense organs. In most forms a pair of highly specialized cerebral sense organs lie in close proximity to the dorsal brain lobes, with which they are completely fused in the Heteronemertea. A pair of lateral sense organs occur on the lateral margins of the body in the nephridial region in many Paleonemertea; frontal sensory pits are found on the tip of the snout in many forms, while Carinoma has a number of sensory pits on the dorsal aspect of the head. Ocelli are often present in considerable numbers, but are wanting in the Paleonemertea and in many species of the Heteronemertea.

The sexes are separate in most species, although a few are hermaphroditic. The sexual products develop in simple sacs in the body parenchyma and are discharged directly upon the surface of the body. Where lateral intestinal lobes are developed the gonads often alternate with them with much regularity.

In the larval development, some forms (Lineidæ) pass through a complicated metamorphosis, with the formation of a free-swimming larva of highly specialized form (pilidium, or Desor's larva),

but in other forms (Amphiporus, Cephalothrix) development is direct, or is accompanied only by a shedding of the larval integument.

Nearly all species are marine, living under stones, among algæ, or in burrows in the sea bottom or shore between tides; representatives of a single widely distributed genus (Stichostemma) live in fresh-water pools, ponds, or rivers, and several species live in moist earth in warm climates; a few forms are commensal, inhabiting the mantle chambers of pelecypods or of ascidians, while the members of a single genus (Carcinonemertes) are truly parasitic, living among the gill plates or egg masses of various species of crabs.

All Nemerteans may be conveniently arranged in four orders, comprising more than thirty genera and several hundred species. Of these, 21 genera with 87 species have been recorded from the Pacific coast, the Nemertean fauna of that region being more abundant and more diversified than in almost any other locality of equal extent.

For convenience in determination, the 87 species at present known from the west and northwest coasts of North America, from Panama to the Bering Sea and Arctic Ocean, may be arranged in the following analytical keys, based mainly on superficial and easily distinguishable characters.

The first key embraces the orders; under each order is given a key to those genera known to occur in the region designated, and under each genus the species there represented.

The geographical distribution, so far as it is known at present, of each of these species is indicated in the keys to species by the following abbreviations: —

N. Arctic Ocean north of Bering Strait.
B. Bering Strait, Bering Sea, Aleutian Islands, Commander Islands.
A. Pacific coast of Alaska.
P. Puget Sound and British Columbia.
C. Central and northern California; Monterey Bay.
S. Southern California; San Pedro and San Diego.
E. Gulf of California and southward to equatorial regions.
X. Eastern coast of North America.
Y. European waters.

A prime mark (′) indicates that the species occurs in deep water off the corresponding coast; the figures following indicate depth in fathoms.

KEY.

1. Without sucking disk ; intestine not convoluted.

2. Proboscis without stylets ; mouth posterior to brain ; intestinal cæcum absent.

3. Muscular walls of body in two layers — outer circular and inner longitudinal — to which a third — inner circular — is sometimes added ; lateral nerves either outside muscular layers or imbedded in longitudinal muscles ; cutis absent . . **Paleonemertea.**

3[1]. Muscular walls of body in three main layers of which the inner is longitudinal ; lateral nerves outside circular muscular layer ; cutis well developed . . . . . . **Heteronemertea.**

2[1]. Proboscis usually provided with stylets ; mouth in front of brain, usually opening with proboscis in a single terminal or subterminal pore ; intestinal cæcum usually present ; lateral nerves internal to muscular layers of body walls . . . . **Hoplonemertea.**

1[1]. With sucking disk at posterior end of body ; intestine convoluted **Bdellonemertea.**

Order **Paleonemertea.**

1. Paired intestinal diverticula absent . . . . **2**.

1. Paired intestinal diverticula present . . . . **3**.

2. Lateral nerves situated immediately outside circular muscles of body walls . . . . CARINELLA.

2. Lateral nerves situated outside muscular layers in esophageal region, but imbedded in longitudinal muscles behind nephridial region ; intestine lobed, but without regularly paired diverticula ; cerebral sense organs wanting . . . . CARINOMELLA.

3. Internal circular muscles enormously developed in nephridial region ; mouth situated immediately behind brain ; body not very slender ; head broader than neck ; nephridia well developed . CARINOMA.

3. Internal circular muscles but little developed in any portion of body ; mouth situated far behind brain ; body filiform ; head sharply pointed CEPHALOTHRIX.

CARINELLA.

1. Body of somewhat homogeneous color, without definite markings . **2**.

1. With distinct longitudinal or transverse markings, or both . . **3**.

2. Body very soft, attaining a length of upwards of 2 meters when fully extended ; deep red, orange, or bright vermilion *C. rubra* Griffin, B, A.

2. Body minute, very slender ; whitish and somewhat translucent *C. pellucida* Coe, C, S, X.

3. Yellow, rosy, or greenish, with black longitudinal and transverse markings. Body large, rather firm, only moderately slender, attaining a length of 50 cm. or more; pale yellowish or rosy, sometimes with greenish tinge, with 3 longitudinal velvety black lines and a series of narrow rings of similar color . . . . . *C. frenata* Coe, S.

3. Red or brown, with white markings . . . . **4.**

4. Deep red, with a series of narrow white rings, but without longitudinal lines. Body firm, rather stout, upwards of 30 cm. long; deep red, with a series of narrow white rings placed at frequent intervals throughout body . . . . *C. albocincta* Coe, S.

4. Brown, with longitudinal and transverse white markings . . **5.**

5. With 3 longitudinal white lines. Slender, up to a meter in length; brown, with numerous narrow transverse rings and 3 parallel longitudinal white lines, of which one is in the dorso-median line and one just below each lateral margin . . . . *C. capistrata* Coe, A, C.

5. With 4, 5, or 6 longitudinal white lines . . . . **6.**

6. Body slender, subcylindrical, 15 cm. or more in length; deep brown, with a series of white rings and 4 longitudinal white lines, of which 2 are lateral, while the other 2 divide dorsal surface of body into three equal parts . . . . *C. cingulata* Coe, C.

6. Body slender, subcylindrical, often half a meter or more in length when fully extended; brown or chocolate, with numerous narrow transverse rings and 5 or 6 parallel longitudinal white lines, of which one is in the median dorsal line, two on each lateral surface, and the sixth, when present, is usually merely indicated in the ventro-median line

C. sexlineata Griffin, A, P, C, S.

CARINOMELLA.

Body slender, usually 5 to 10 cm. in length; milk-white and somewhat translucent, sometimes with yellowish or brownish intestinal canal

C. lactea Coe, S.

CARINOMA.

Body rather stout, flattened posteriorly; milk-white with grayish or brownish mottlings and darker intestinal lobes

C. mutabilis Griffin, P, C, S.

CEPHALOTHRIX.

Slender, filiform: pale yellow, sometimes with reddish, grayish, or greenish tinge; no ocelli in adult

C. linearis (Rathke) Oersted, B, A, P, C, S, X, Y.

Order **Heteronemertea.**

1. Proboscis musculature of two layers, of which the outer is circular; muscular crosses absent in proboscis; cephalic glands usually very voluminous, extending posteriorly behind the brain; cephalic furrows absent . . . . TÆNIOSOMA.

1. Proboscis musculature of two or three layers, of which the outer is longitudinal; muscular crosses present in proboscis; cephalic glands usually but little developed, and not extending posterior to brain . **2**.

2. Without horizontal cephalic furrows on sides of head; caudal cirrus present . . . . ZYGEUPOLIA.

2. With conspicuous horizontal cephalic furrows on sides of head . **3**.

3. Caudal cirrus absent: proboscis sheath usually considerably shorter than body . . . . **4**.

3. Caudal cirrus present: proboscis sheath usually extends nearly or quite to posterior end of body . . . . **5**.

4. Body remarkably thick and massive, usually nearly cylindrical when fully extended, but very broad and much flattened in intestinal region when strongly contracted: ocelli wanting: muscular layers of body possess a reddish tinge . . . . EUBORLASIA.

4. Body long and slender, rounded or flattened, very contractile: ocelli present in most species . . . . LINEUS.

5. Body rather firm, lateral margins not remarkably thin: incapable of swimming; neurochord cells absent in many species . . MICRURA.

5. Body usually long and ribbon-like, much flattened, with very thin lateral margins and well adapted for swimming: dorso-ventral and diagonal muscles well developed: neurochord cells present in many species CEREBRATULUS.

TÆNIOSOMA.

1. With narrow transverse rings of white throughout length of body. Body of moderate diameter, but of great length, often exceeding 2 meters, somewhat flattened: brown, with a great number of narrow rings of whitish encircling the body . *T. mexicana* Bürger. E.

1. Without white rings . . . . **2**.

2. Yellow, thickly sprinkled with small, irregular, dark red spots: body of very large size, sometimes 2 meters or more in length and 18 mm. in diameter . . . . *T. princeps* Coe, A, P.

2. Deep red, mahogany, or reddish brown, sometimes covered with whitish bloom: head with broad spot of darker color and terminal border of white: ventral surface of same general color as dorsal, but paler, except ventral side of head, which is whitish: body large, soft, flabby, 40 to 60 cm. in length . . . . . *T. punnetti* Coe, C. S.

ZYGEUPOLIA.

Slender, 5 to 10 cm. in length; head acutely pointed; cephalic furrows absent, the canal from each cerebral sense organ opening into a small pit on side of head; caudal cirrus conspicuous; whitish or flesh-color, becoming yellowish, rosy, or pale brown in intestinal region and pure white on head . . . . *Z. littoralis* C. B. Thompson, S, X.

EUBORLASIA.

Of gigantic size for a worm, with a greater diameter than in any other described species of Nemertean, becoming 45 mm. wide in intestinal region; dark brown, perhaps with an olive tinge; head paler, with brown mottlings . . . . . . *E. maxima* Coe, E.

LINEUS.

1. Snout and body not strikingly different in color; without distinct markings . . . . **2**.

1. Snout and body of different color, or with distinct markings on body **3**.

2. Dusky or brownish green, dark brown, or reddish brown, commonly paler beneath; a single row of 4 to 8 ocelli on each side of head *L. viridis* (Fabr.) Johnston, A, X, Y.

2. Yellowish, pale yellow with tinge of orange, dull orange, ochre, buff, or yellowish brown; margins of head pale or colorless; with 3 to 7 irregular red, purple, or black ocelli, of which the most anterior are largest *L. flavescens* Coe, S.

3. With conspicuous median dorsal stripe, but without transverse markings.

Deep brown or olive, with median dorsal stripe of white or lemon yellow extending whole length of body and widening out on head to form a broad white marking . . . . *L. albolineatus* Coe, C, S.

3. Without conspicuous median dorsal stripe . . . . . . **4**.

4. With one or more narrow transverse rings of paler color . . **5**.

4. Without transverse rings of paler color. Pink, rosy flesh-color, or pinkish red, sometimes with tinge of blue; snout white both above and below, sharply marked off from rosy color of body: often with bluish tinge after preservation . . *L. rubescens* Coe, C, S.

5. With a single narrow whitish band on dorsal side of head, connecting posterior ends of cephalic furrows.

Body and head dark reddish brown or purple . *L. torquatus* Coe, A.

5. With numerous delicate rings of white or yellowish . . . **6**.

6. Soft and flabby; deep brown, chestnut, or slaty, sometimes with green-

ish tinge; with transverse lemon yellow rings at intervals along whole length of body and with 7 to 15 very inconspicuous, fine, hair-like longitudinal lines of yellow on dorsal surface: of these latter the median line is more distinct than the others and connects the diamond-shaped enlargements of the transverse rings; tip of snout white, usually with 2 orange colored spots *L. pictifrons* Coe, S, E.

6. Slender; deep brown, chocolate, or drab, paler beneath, with series of very narrow and inconspicuous white rings; tip of snout and borders of cephalic furrows white . . . . *L. wilsoni* Coe, C, S.

MICRURA.

1. With conspicuous transverse rings of white . . . . . 2.
1. Without conspicuous transverse rings . . . . . . 3.
2. Deep purple or reddish brown above, with a series of narrow transverse rings throughout length of body; pure white beneath and on lateral margins of body; tip of snout deep orange or vermilion: caudal cirrus white, conspicuous . . . . . *M. verrilli* Coe, A, P, C.
2. Dusky gray above, with narrow colorless transverse bands: head flesh-colored . . . . . . *M. impressa* (Stimpson) Coe, B.
3. Dorsal surface with conspicuous spots and blotches . . . 4.
3. Without distinct spots, except on tip of snout . . . . . 5.
4. Pale yellow, thickly covered on dorsal surface only with black or dark brown spots and dots, often somewhat elongated and arranged in irregular longitudinal lines; a single row of 10 to 18 ocelli on each side of head; nephridia limited to middle third of esophageal region; body rather stout, much flattened . . *M. pardalis* Coe, C.
4. Grayish after preservation (color in life unknown), thickly mottled on both dorsal and ventral surfaces with coarse confluent brownish blotches, which often fuse together posteriorly to form a continuous brownish color; nephridia extend forward to mouth region
M. nebulosa Coe, A', 483.
5. Rosy, flesh-color, or red; ocelli wanting . . . . . . 6.
5. Olive, ochre, or buff; ocelli present.
Pale olive brown, grayish ochre, or buff; deeper brown in intestinal region, and with a paler median dorsal stripe in esophageal region; 6 to 12 or more small black ocelli in an irregular row or elongated cluster on each side of head . . . . . *M. olivaris* Coe, S, C', 68.
6. Deep red; tip of snout with black spot surrounded by narrow ring of white.
Sometimes purplish in esophageal region and brighter red anteriorly: head bright red with a narrow, but very sharp and conspicuous, transverse band of white just behind tip of snout, which is red with a small, dark brown or black spot on the exact tip . *M. nigrirostris* Coe, S.

6. Paler, without black spot on snout . . . . 7.
7. Rosy or pinkish red with purplish tinge in esophageal region, becoming gradually paler toward snout, which is white; intestinal region deep flesh-color, pale red, or yellowish; accessory buccal glands wanting
M. griffini Coe, S.
7. Salmon or flesh-color (rarely light, rosy brown); shading into lighter, with tinges of brighter red, or nearly white anteriorly; intestinal lobes more deeply colored, sometimes brown; a cream-colored stripe is situated in median ventral line; accessory buccal glands well developed
M. alaskensis Coe, A, C, S.

CEREBRATULUS.

1. Snout whitish both above and below, strikingly different from deep color of body . . . . 2.
1. Snout not strikingly different from body in color . . . . . 3.
2. Body very long and ribbon-like, attaining a length of more than two meters; deep blood-red, except tip of snout, which is yellowish white, above and below . . . *C. montgomeryi* Coe, B, A, P, B′, 85.
2. Body long and ribbon-like, very dark brown or reddish purple, except head, which is white on both dorsal and ventral surfaces, back about three fourths the length of the cephalic furrows, or sometimes nearly or quite to the mouth . . . . *C. albifrons* Coe, A, P, C, S.
3. Without distinct longitudinal or transverse markings on body . 4.
3. With conspicuous transverse or longitudinal markings on body . 9.
4. Black, brown, reddish brown, olive, or dark gray, sometimes with paler lateral margins . . . . 5.
4. Rosy flesh-color, cream-color, or buff: head paler, brain and lateral nerves reddish and conspicuous in life, intestinal region cream-colored or pale buff; body remarkably fragile. *C. californiensis* Coe, S, S′, 28.
5. Body long and ribbon-like . . . . 6.
5. Body comparatively short and broad . . . . 8.
6. Head very long and slender: nephridia with very numerous efferent ducts.

Dark brown or purplish, paler on borders of cephalic furrows and tip of snout; head and anterior portions of body very slender, with remarkably long and deep cephalic furrows . . . *C. longiceps* Coe, A.
6. Head of moderate proportions, or short . . . . 7.
7. Slaty brown to grayish or pale olive, paler beneath and often with conspicuously paler or white lateral margins
C. marginatus Renier, A, P, C, S, X, Y.
7. Dark reddish brown; body very large and stout, becoming 2 meters or more in length and 25 mm. in width: head and cephalic furrows short
C. herculeus Coe, A.
8. Chestnut brown or reddish in esophageal region, chocolate brown pos-

teriorly; brownish flesh-color to reddish brown beneath, usually with median longitudinal ochre stripe along ventral surface

C. occidentalis Coe, A, P.

8. Brown or olive, ventral surface and lateral margins of body paler; body remarkably broad and much flattened, with very thin lateral margins; head very broad, with remarkably short cephalic furrows

C. latus Coe, A, B′, A′, P′, C′, 40–135.

9. Rather slender; pale gray with numerous fine, irregular and much interrupted dark olive brown longitudinal lines extending whole length of body both above and below, but more numerous and larger on dorsal surface than ventrally . . . . . *C. lineolatus* Coe, S.

9. Rather short: with conspicuous narrow band of dark color in median dorsal line, and a series of narrow transverse markings of dark color placed side by side on dorso-lateral aspects of body. Other markings may possibly be present in life . . . *C. signatus* Coe, B′, 61.

Order **Hoplonemertea**.[1]

1. Body provided with a pair of conspicuous lateral swimming appendages. or cirri, immediately back of head; posterior extremity broad and finlike; proboscis without stylets . . . NECTONEMERTES.

1. Body without lateral appendages . . . . **2**.

2. Proboscis sheath not more than three fourths the length of body; body long and slender . . . . **3**.

2. Proboscis sheath extends nearly or quite to posterior end of body: body usually not very slender . . . . **6**.

3. Proboscis sheath less than half the length of body: proboscis of small size . . . . **4**.

3. Proboscis sheath one half to three fourths the length of body: proboscis well developed . . . . PARANEMERTES.

4. Accessory stylets present . . . . **5**.

4. Accessory stylets absent: proboscis and sheath very rudimentary, with central stylet only; parasitic . . . . CARCINONEMERTES.

5. Ocelli minute and usually numerous . . . . EMPLECTONEMA.

5. Ocelli large, four in number: body filiform . . . NEMERTOPSIS.

6. Proboscis provided with stylets, intestine not dendrocœlous . **7**.

6. Proboscis without stylets; intestine dendrocœlous; pelagic

PLANKTONEMERTES.

7. I.oboscis sheath without cæcal appendages: proboscis armed with single central stylet besides 2 or more pouches of accessory stylets . **8**.

[1] In addition to the marine Nemerteans here included, a representative of the fresh-water genus (Stichostemma) has been found in pools in the vicinity of Seattle, Washington.

7. Proboscis sheath provided with cæcal appendages ; proboscis armed with central plate bearing a number of stylets besides several pouches of accessory stylets . . . . Drepanophorus.

8. Ocelli numerous, extending posteriorly along lateral nerve cords beyond the brain ; basis of central stylet massive, with flattened or concave posterior end . . . . Zygonemertes.

8. Ocelli do not extend posteriorly beyond brain ; basis of central stylet commonly (but not always) rounded posteriorly . . . . . 9.

9. Body usually not very small ; ocelli usually numerous, always more than 4 in the known Pacific coast species . . . . . Amphiporus.

9. Body very small ; ocelli usually 4, arranged in rectangle ; occasionally each of the four ocelli is double or fragmented into groups ; rarely ocelli are entirely wanting . . . . . . Tetrastemma.

Emplectonema.

1. Dorsal surface green ; central and accessory stylets curved ; stylets long and slender ; basis very long ; body dark or pale green dorsally ; whitish, yellowish, or very pale green ventrally
E. gracile (Johnston) Verrill, B, A, P, C, Y.

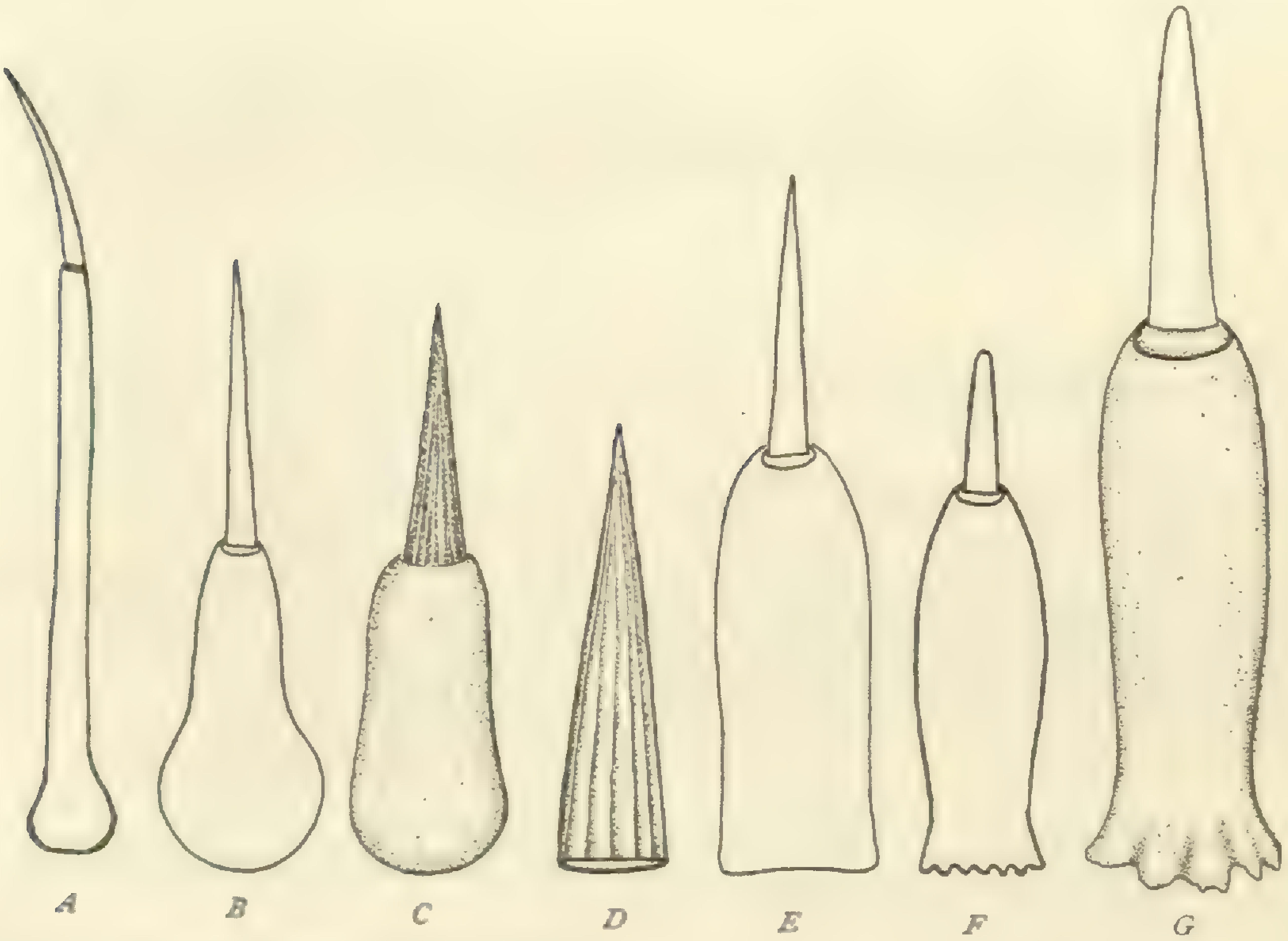


Fig. 1.— Outlines of central stylets and bases.
A, *Emplectonema gracile*.
B, *E. bürgeri*.
C, *E. purpuratum*.
D, *E. purpuratum*. Central stylet more highly magnified.
E, *Zygonemertes albida*.
F, *Z. thalassina*.
G, *Z. virescens*.

1. Dorsal surface brown or purplish ; central and accessory stylets straight **2.**

2. Stylets short, with swollen heads ; basis of central stylet swollen and rounded posteriorly ; 11 proboscidial nerves ; dark brown above, often with minute purple dots ; flesh-colored or yellowish white beneath *E. bürgeri* Coe, A, P.

2. Stylets without swollen heads, fluted longitudinally ; basis of central stylet not swollen posteriorly ; 16 proboscidial nerves ; purplish or purplish brown from closely placed mottlings on dorsal surface ; ventral surface gray or yellowish . . . . *E. purpuratum* Coe, B.

NEMERTOPSIS.

Filiform, often 15 cm. or more in length ; very pale brown or whitish, with 2 longitudinal dorsal stripes of deep brown ; 8 proboscidial nerves *N. gracilis* Coe, C.

CARCINONEMERTES.

Length when sexually mature but 4 to 6 mm. ; with 2 large ocelli ; orange or reddish ; parasitic on egg masses of *Epialtus productus* and perhaps other crabs . . . . *C. epialti* Coe, C.

PARANEMERTES.

1. White or flesh-color . . . . **3.**

1. With orange, green, brown, or purple tints . . . . . . **2.**

2. With 2 or 4 pouches of accessory stylets ; 14 proboscidial nerves ; stylets have braided appearance ; purplish brown, dark brown, or orange brown above, on sides, and on lateral margins of ventral surface ; with a whitish angular spot on each side of head ; ventral surface, often median third only, white or yellowish white *P. peregrina* Coe, B, A, P, C, S.

2. With 4 or 6 pouches of accessory stylets ; 10 large proboscidial nerves ; translucent ; pale orange anteriorly ; flesh-color, grayish, or very pale salmon posteriorly, much obscured by deep green color of intestinal tract . . . . *P. californica* Coe, S.

3. With 4 pouches of accessory stylets ; 9 or 10 proboscidial nerves ; opaque white . . . . *P. pallida* Coe, A.

3. With 6 or 12 pouches of accessory stylets ; 11 or 12 proboscidial nerves ; whitish, pinkish, or flesh-color . . . . *P. carnea* Coe, A, P.

ZYGONEMERTES.

1. Central stylet short and stout . . . . **2.**

1. Central stylet rather slender.

Whitish, with tinge of yellow: ocelli extend along lateral nerves for about two fifths the length of esophageal region; body small

Z. albida Coe, P.

2. Pale green; occasionally flesh-colored, pale yellow, or white, especially anteriorly: central stylet short, about half as long as basis, not remarkably stubby; usually 2 or 3 accessory stylets in each of 2 lateral pouches; 10 or 11 proboscidial nerves

Z. virescens (Verrill) Montgomery, C, S, X.

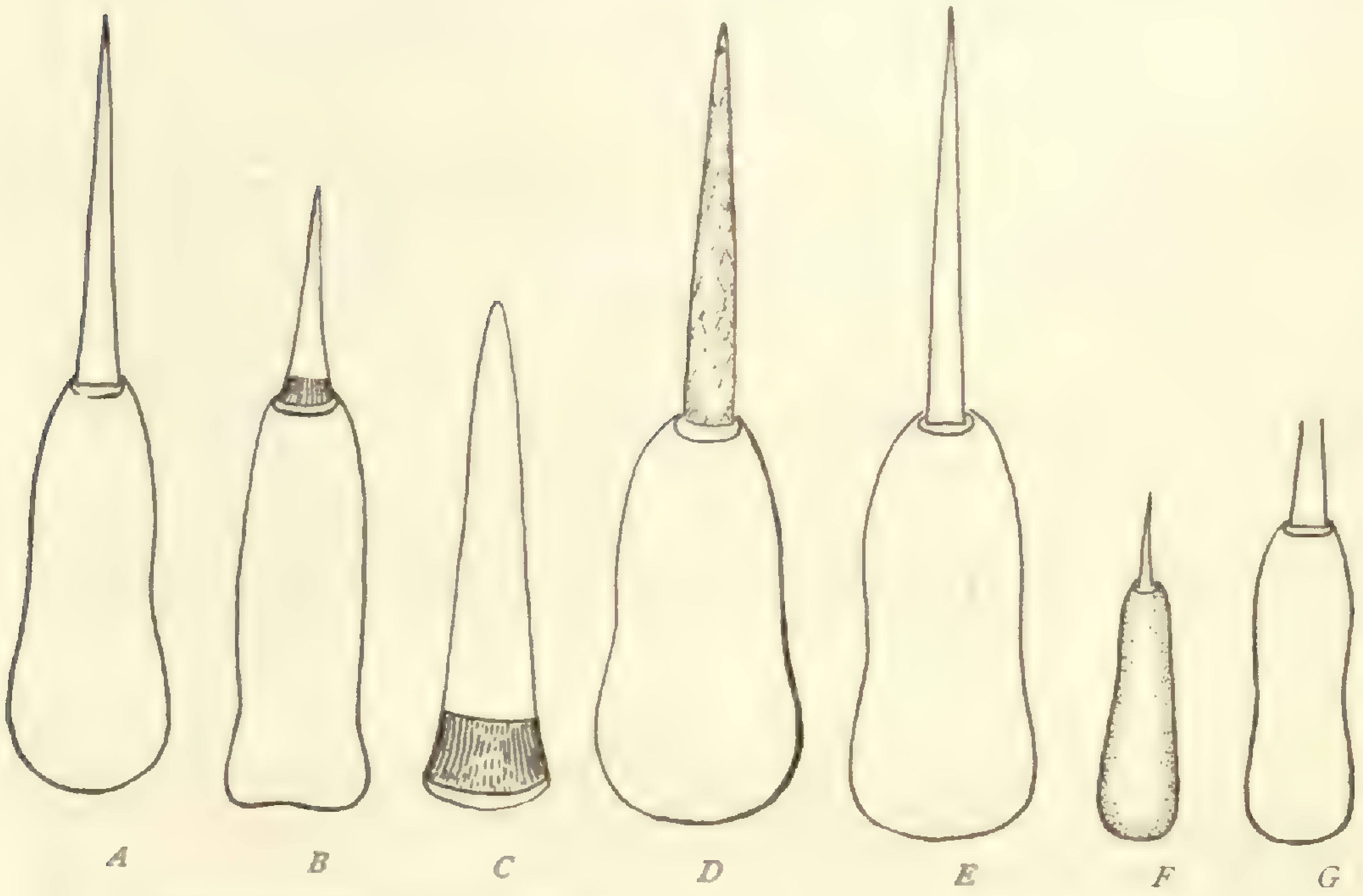


FIG. 2.—Outlines of central stylets and bases.
A, *Paranemertes carnea.*
B, *P. californica.*
C, *P. californica.* Stylet only, more highly magnified.
D, *P. peregrina.*
E, *P. pallida.*
F, *Carcinonemertes epialti.*
G, *Nemertopsis gracilis.*

2. Dark olive green; central stylet remarkably stubby, often less than half as long as basis which is much serrated on posterior border: commonly 5 accessory stylets in each of 2 lateral pouches; 12 proboscidial nerves

Z. thalassina Coe, A.

AMPHIPORUS.[1]

1. Body very gelatinous, with an enormous development of the body parenchyma.

Body short and broad: ocelli large, 30 or more on each side of the head; cerebral sense organs extremely small, situated in front of brain

A. gelatinosus Coe, A′, 159.

[1] In addition to the forms here included, two species, *A. brunneus* and *A. drepanophoroides*, have been described by Griffin from Puget Sound, but their diagnoses are so incomplete that it is doubtful as to which, if any, of these forms they should be referred.

1. Body contains only a moderate amount of parenchyma . . . . **2.**

2. Esophagus provided with large cæcum extending on ventral side of esophagus proper and ending blindly posteriorly . . . . . **19.**

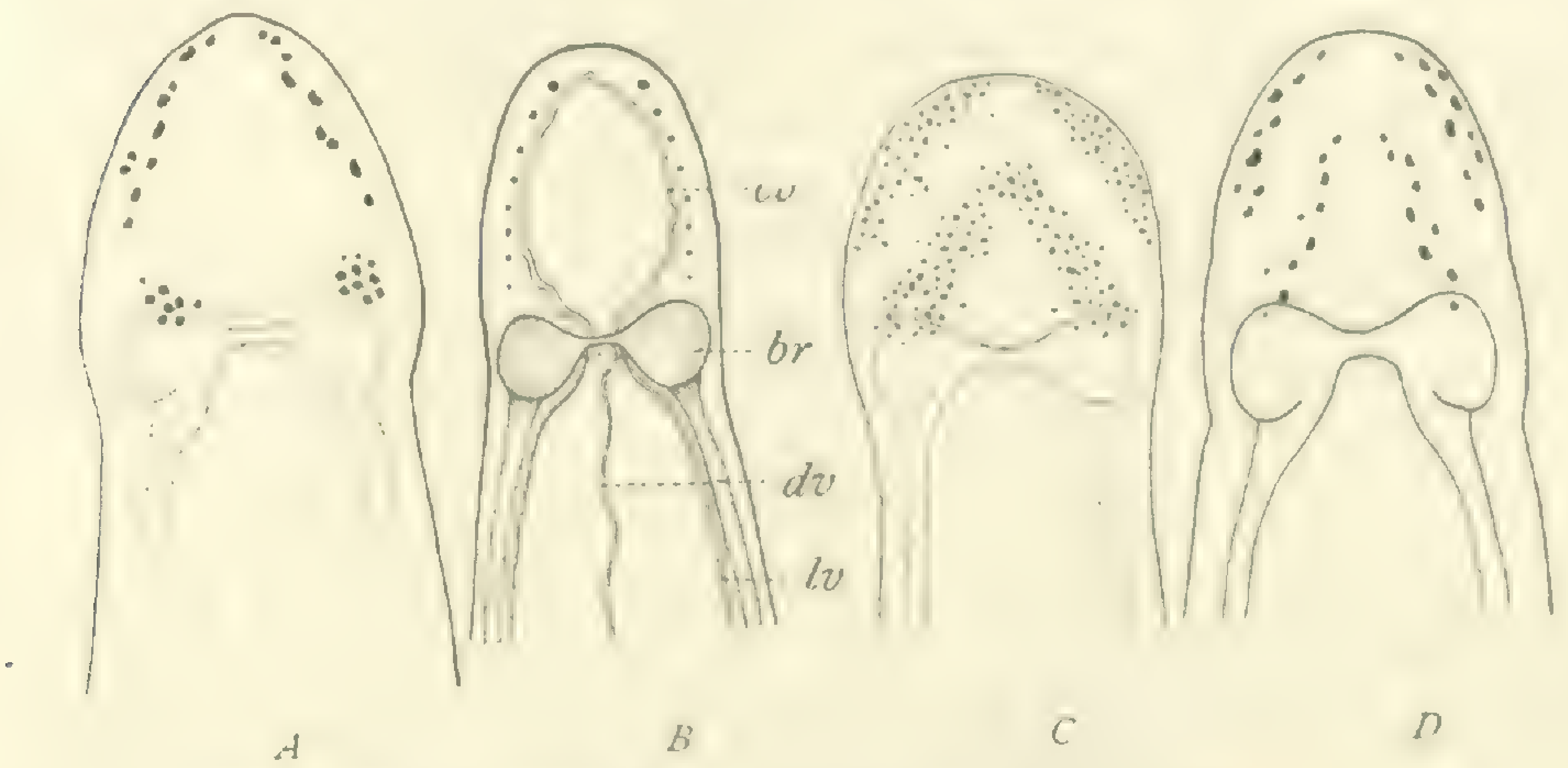


FIG. 3.—Outlines of heads, showing number and arrangement of ocelli.
A, *Paranemertes peregrina.*
B, *Amphiporus cruentatus*; *br*, brain, *cv*, *dv*, *lv*, cephalic, dorsal, and lateral vessels respectively.
C, *A. formidabilis.*
D. *A. imparispinosus.*

2. Esophagus without ventral cæcum . . . . **3.**

3. Proboscis usually provided with only two pouches of accessory stylets **4.**

3. Proboscis provided with more than 2 pouches of accessory stylets **16.**

4. Ocelli in a single row on each side of head.

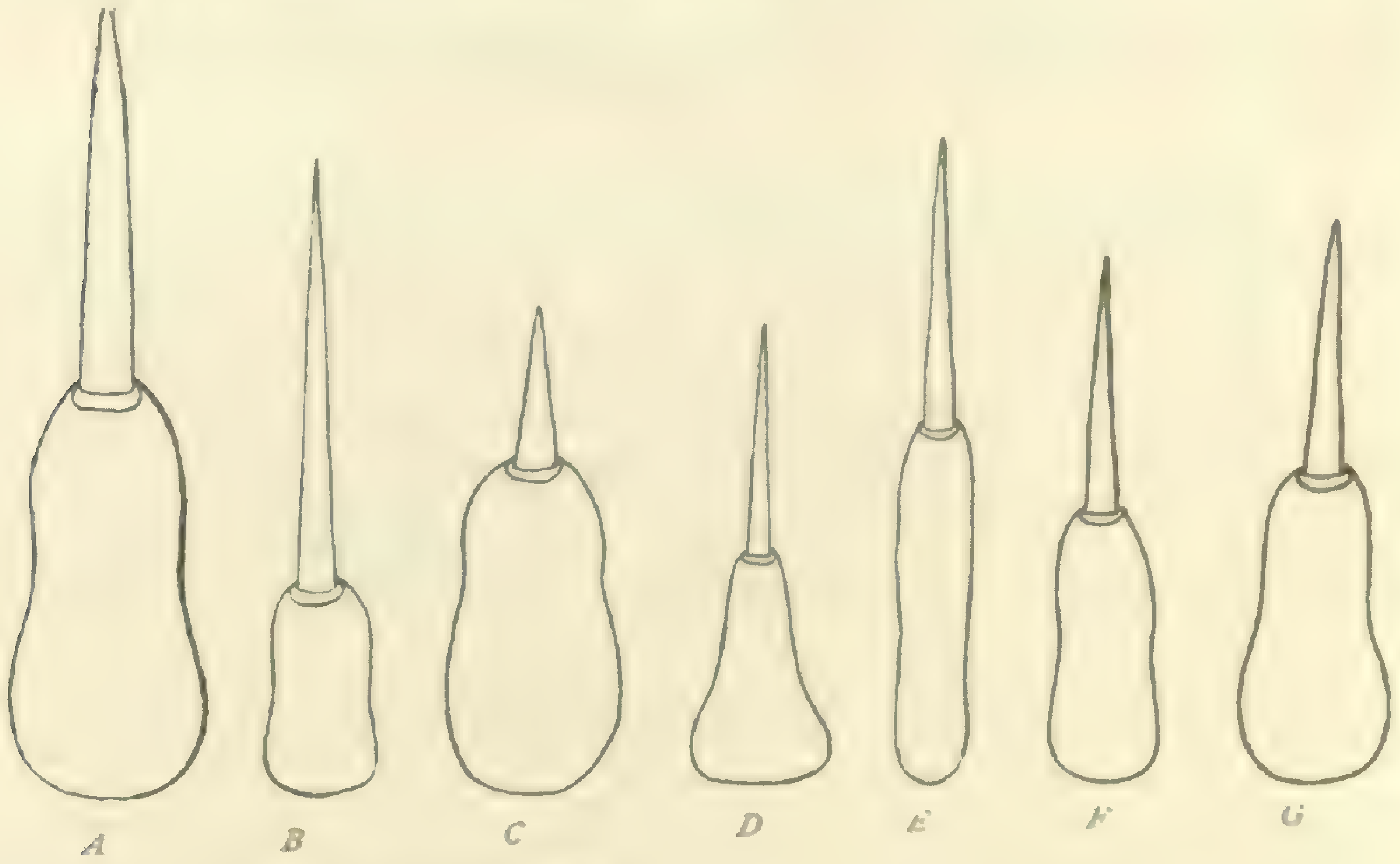


FIG. 4.—Outline of central stylets and bases.
A, *Amphiporus angulatus.*
B, *A. bimaculatus.*
C, *A. tigrinus.*
D, *A. nebulosus.*
E, *A. cruentatus.*
F, *A. similis.*
G, *A. imparispinosus.*

Body rather slender; 10 to 25 mm. in length: color yellow; blood vessels deep red in color; basis and stylet both very slender and of about equal length . . . . . *A. cruentatus* Verrill, C, S, X.

4. Ocelli scattered, and not in a single row on each side of head[1] . **5.**

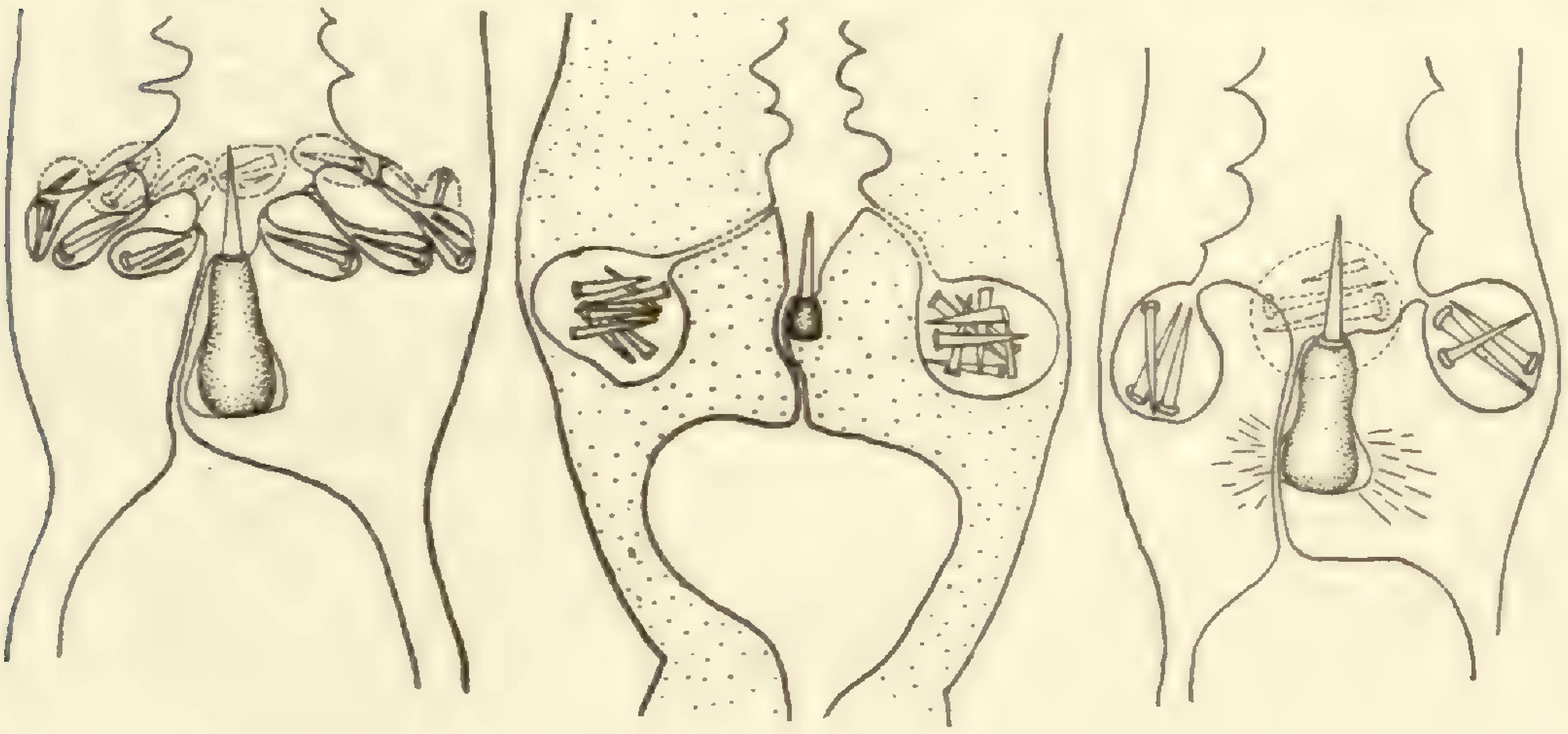
5. Central stylet as long as basis, or considerably longer . . . **6.**

5. Central stylet considerably shorter than basis . . . . . . **14.**

6. Central stylet and basis of about equal length . . . . . **8.**

6. Central stylet about twice as long as basis . . . . . . **7.**

7. Body rather broad and flattened: orange, brownish, or reddish above, with 2 large dark brown or black elongated spots on head; ventral sur-



A B C

FIG. 5.—Outlines of stylet apparatus.
A, *Amphiporus formidabilis*, with 12 pouches of accessory stylets.
B, *A. punctatulus*, with 2 pouches of accessory stylets.
C, *A. imparispinosus*, with 3 pouches of accessory stylets.

face pale orange or flesh-color; sometimes with 4 pouches of accessory stylets; stylets very slender; 14 or 16 proboscidial nerves; cerebral sense organs beside brain . . . *A. bimaculatus* Coe, A, P, C.

7. Body rather short and thick; mottled thickly with dark brown dots and blotches; stylets dagger-shaped; 5 to 8 or more in each of the two lateral pouches; basis barrel-shaped: 12 or 13 proboscidial nerves; cerebral sense organs large, situated beside brain

A. punctatulus Coe, S (at surface).

8. Cerebral sense organs in front of brain . . . . . . **9.**

8. Cerebral sense organs beside brain.

Body short and broad; color reddish or brownish above, pale beneath;

[1] In a single species (*A. leptacanthus*) belonging to this group the relative length of stylet and basis is as yet unknown, and the species is not included in this key. Color of body whitish, with tinge of yellow or brown; basis of central stylet remarkably slender, four or five times as long as broad; ocelli 16–24 in a single irregular cluster on each side of head.

basis rather slender, or ordinary shape; 14 proboscidial nerves; cerebral sense organs very large *A. pacificus* Coe, B′, A′, C′, 47–97.

9. With numerous spots and blotches on dorsal surface.

Rather broad and flat; whitish, thickly mottled with dark brown blotches and dots; ventral surface whitish; basis of central stylet bell-shaped, broad and flattened posteriorly; stylets slender; 17 proboscidial nerves *A. nebulosus* Coe, A.

9. Dorsal surface without distinct spots . . . . **10.**

10. Red, orange, brown, or purplish above; pale or whitish ventrally . **11.**

10. Whitish, flesh-color, yellow, or pale reddish . . . . . **12.**

11. With 17 to 20 proboscidial nerves; basis of moderate proportions; body short and broad; dark purplish or chocolate brown above, with a

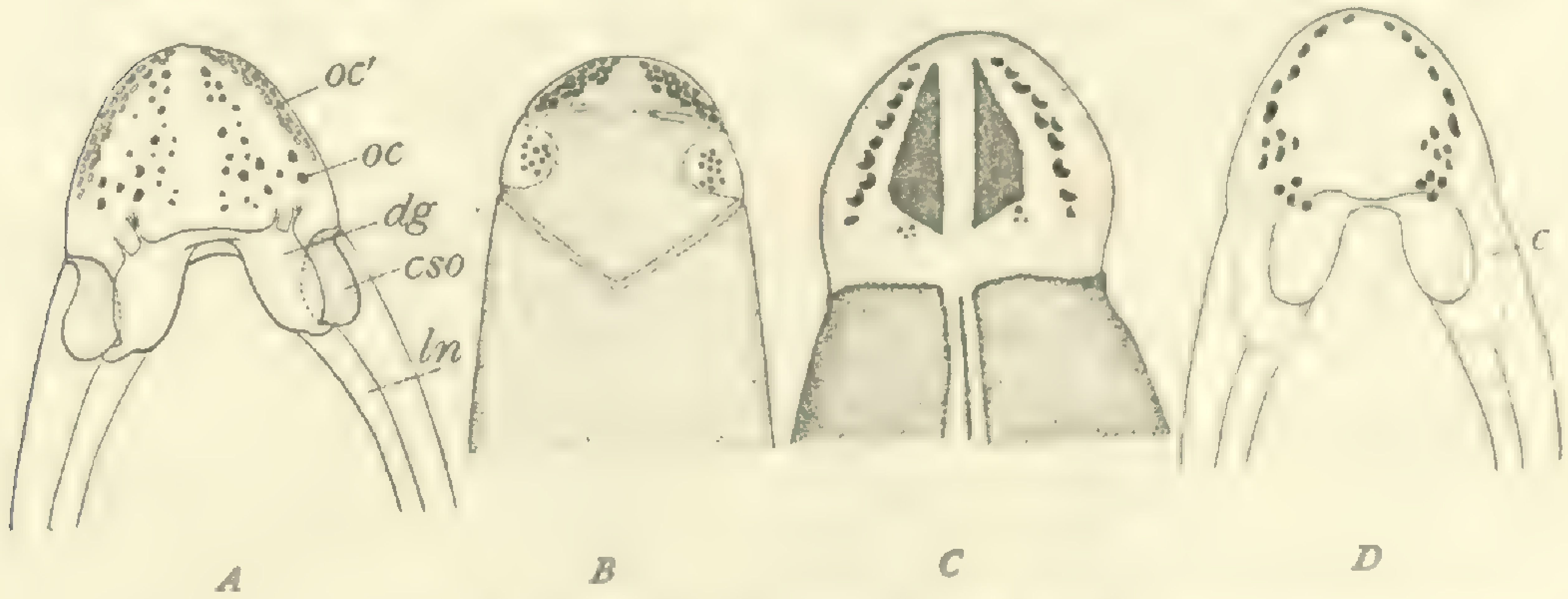


FIG. 6.—Outlines of heads, showing number and arrangement of ocelli.

A, *Drepanophorus ritteri*; *oc* and *oc′*, ocelli of dorsal and ventral surfaces of head respectively; *dg*, dorsal ganglion; *cso*, cerebral sense organ; *ln*, lateral nerve.

B, *Amphiporus angulatus*.

C, *A. bimaculatus*.

D, *A. punctatulus*; *c*, cerebral sense organ.

triangular white spot on each side of head; ventral surface pinkish or flesh-color . . . . . *A. angulatus* (Fabr.) Verrill, B, A, P, X.

11. With 10 to 12 proboscidial nerves; body small, rather short and broad; reddish or orange, paler beneath; ocelli usually only 4 to 8 on each side of head; basis conical, stylets slender.
A. californicus Coe, S, S′, 50.

12. With 10 or 11 proboscidial nerves . . . . **13.**

12. With 15 proboscidial nerves.

Whitish; very slender; submuscular glands well developed; intestinal cæcum short . . . . . . *A. paulinus* Punnett, B.

13. Small; of moderate proportions; whitish, pale flesh-color, yellowish, ochre, or pale orange; ocelli commonly 10 to 50; basis of central stylet bell-shaped; 10 or 11 proboscidial nerves . *A. flavescens* Coe, C, S.

13. Very small and slender; whitish; ocelli commonly 10 to 20, in four groups; 1 to 3 accessory stylets in each pouch; 10 proboscidial nerves *A. similis* Coe, C.

14. Central stylet about three fourths as long as basis.

Body small, slender, rounded : brownish, with minute dark brown dots ; 25 or more ocelli ; basis of central stylet bell-shaped ; cerebral sense organs large, situated close in front of brain . *A. fulvus* Coe, S

14. Central stylet not more than half as long as basis . . . **15**.

15. Central stylet about half as long as basis.

Body rounded, rather slender ; color of females yellowish orange, obscured in intestinal region by dark green ova in breeding season ; males yellowish, with white flecks ; basis massive, rounded posteriorly ; cerebral sense organs in front of brain . . *A. tigrinus* Coe, P.

15. Central stylet about one third as long as the remarkably massive basis.

Body short and rounded ; proboscis remarkably large, provided with 10 nerves : basis larger than in any other known species, measuring about a millimeter in length and easily visible to the unaided eye ; stylets short and conical . . . . *A. macracanthus* Coe, N.

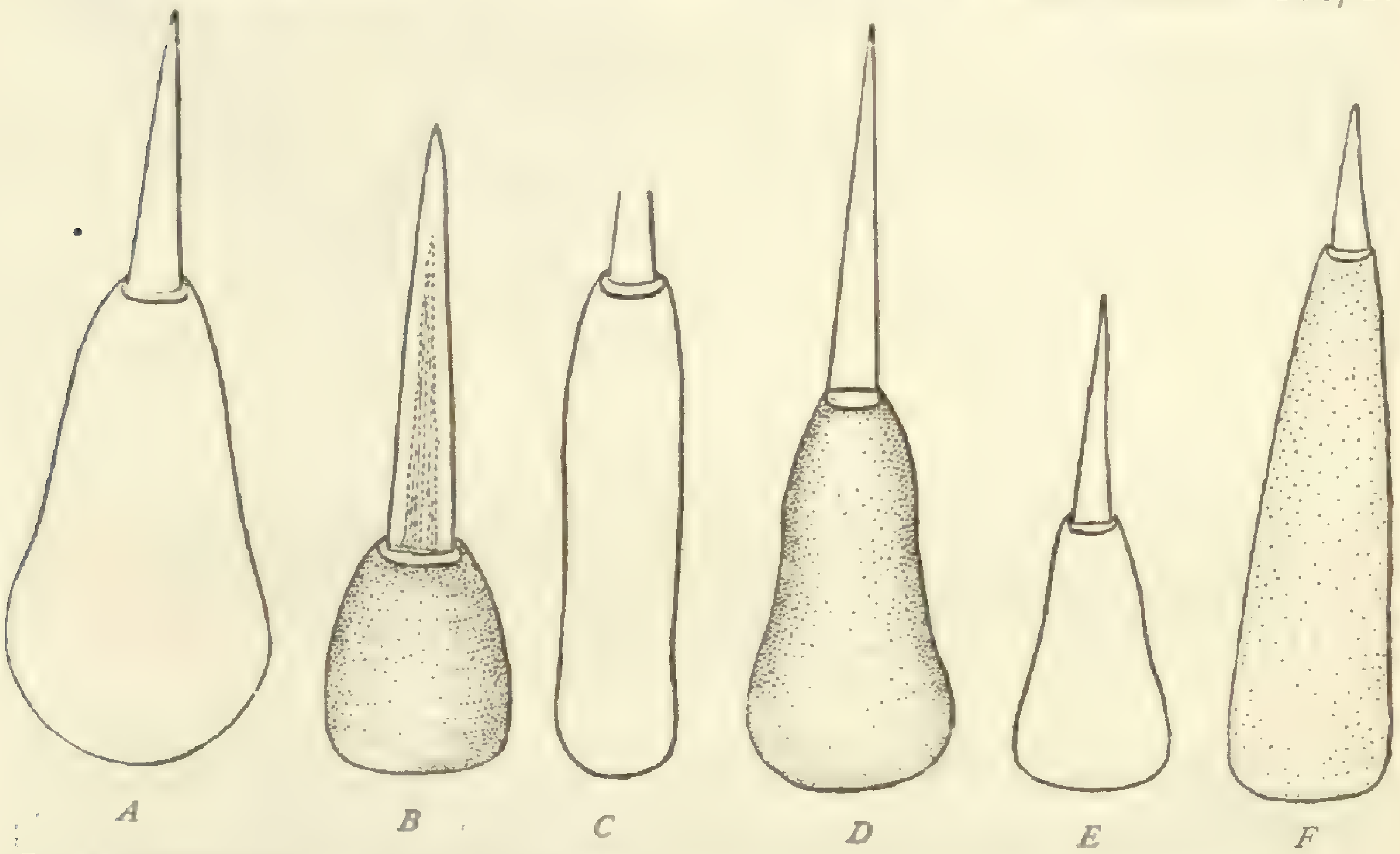


FIG. 7.—Outlines of central stylets and bases.
A, Amphiporus formidabilis.
B, A. punctatulus.
C, A. leptacanthus.
D, A. californicus.
E, A. flavescens.
F, A. macracanthus.

16. With 3 pouches of accessory stylets.

White : body slender ; ocelli usually less than 40 ; commonly 4 to 8 nephridiopores on each side, some of which are situated on dorsal side of body . . . . . *A. imparispinosus* Coe, B, A, P, C, S.

16. With 4 or more pouches of accessory stylets . . . . **17**.

17. With 4 (or sometimes 2) pouches of accessory stylets . . . **18**.

17. With 6 to 12 pouches of accessory stylets.

Body very slender ; color whitish or flesh-color ; ocelli usually 60 to 250 ; commonly 20 or more nephridiopores on each side, most of which are situated on dorsal side of body . *A. formidabilis* Coe, B, A, P, C.

18. Orange, brownish, or reddish above, with 2 large dark brown or black

angular spots on head; ventral surface pale orange or flesh-color; 14 or 16 proboscidial nerves . . *A. bimaculatus* Coe, A, P, C.

18. Dark brown or purplish, with small, angular white spot on each side of head; ventral surface pink or flesh-color; 17 to 20 proboscidial nerves; occasionally with 4 pouches of accessory stylets *A. angulatus* (Fabr.) Verrill, B, A', P, X.

19. Esophageal cæcum terminates posteriorly in front of anterior ends of intestinal cæca; body parenchyma comparatively well developed; ocelli few . . . . *A. rubellus* Coe, S', 20–50.

19. Esophageal cæcum extends posteriorly far beyond anterior ends of intestinal cæca; body parenchyma but little developed; ocelli numerous . . . . *A. occidentalis* Coe, P', 40–97.

Tetrastemma.

1. With 4 well developed ocelli . . . . 2.
1. Ocelli fragmented or wanting . . . . 9.

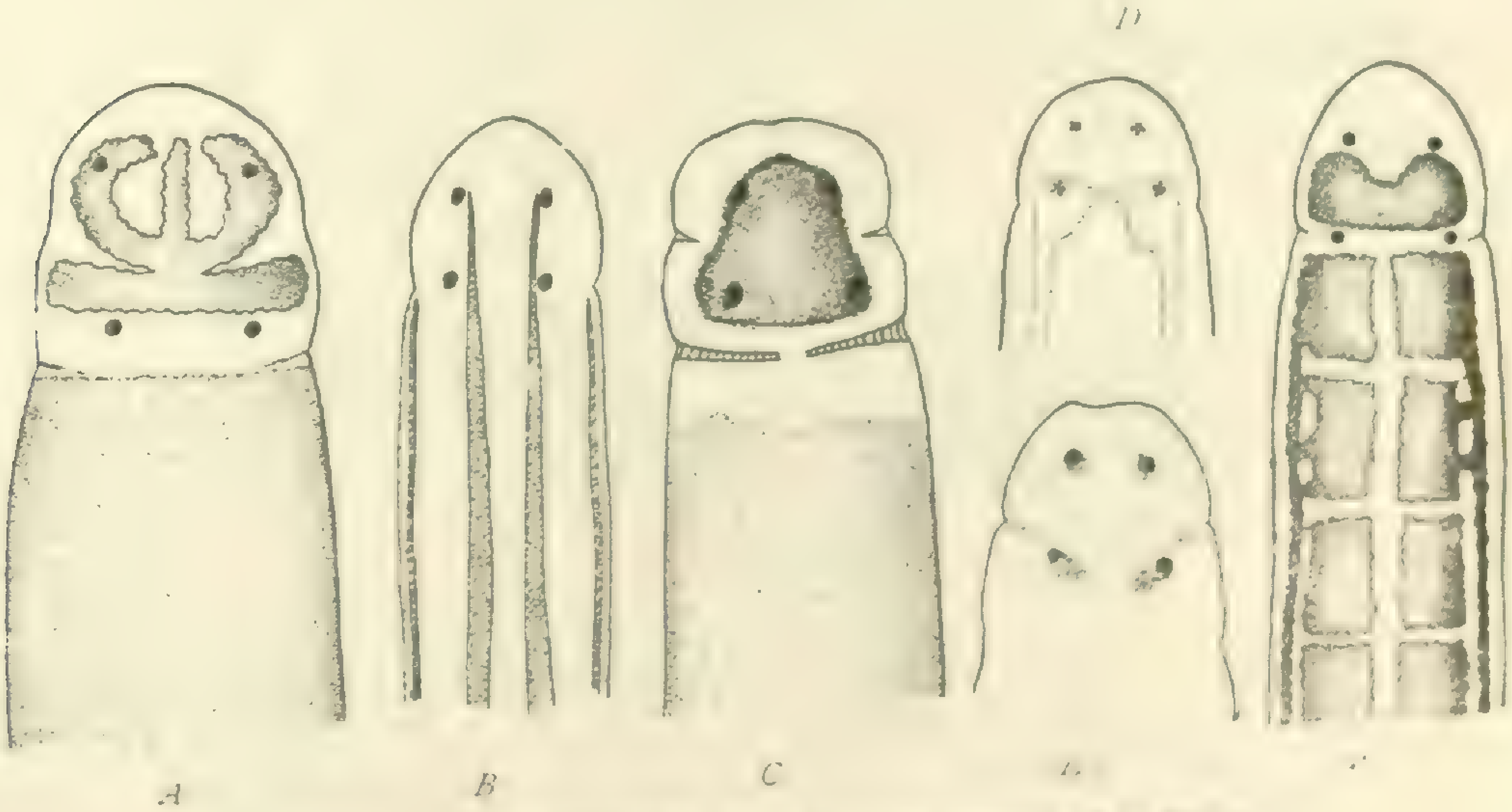


Fig. 8.— Outlines of heads, showing position of ocelli and arrangement of markings.
A, Tetrastemma signifer.
B, T. quadrilineatum.
C, T. nigrifrons.
D, T. aberrans.
E, T. albidum.
F, T. reticulatum.

2. Body not especially firm, somewhat flattened . . . . . 3.
2. Body remarkably firm, cylindrical . . . . (Œrstedia.) 8.
3. With distinct longitudinal brown stripes on dorsal surface . . 4.
3. Without distinct longitudinal stripes of brown on dorsal surface . 5.
4. Flesh-color, creamy, or grayish, with 2 deep brown longitudinal stripes on dorsal surface; 5 to 10 mm. in length . *T. bilineatum* Coe, S.
4. Whitish, with 4 deep brown longitudinal stripes, of which 2 lie on lateral margins and 2 on dorsal surface; 8 to 12 mm. in length *T. quadrilineatum* Coe, S.
5. Blood corpuscles distinctly red . . . . 6.

5. Blood corpuscles pale or colorless.

Body very slender, usually 10 to 15 mm. in length; milk-white, creamy, or flesh-colored; basis of central stylet very slender: cerebral sense organs remarkably large, situated beside brain

T. albidum Coe, C, S.

6. With large black or deep brown marking on dorsal side of head . **7**.

6. Head without conspicuous marking.

Body 30 to 60 mm. in length; brownish red above with median white stripe; ventral surface white: without conspicuous lateral grooves on head . . . . *T. bicolor* Coe, A.

7. Cephalic marking wreath-like.

Rather slender, 15 to 25 mm. in length; reddish brown both above and below, except head which is white with a sharply marked wreath of deep brown color on dorsal surface . . . *T. signifer* Coe, S.

7. Cephalic marking triangular or shield-shaped.

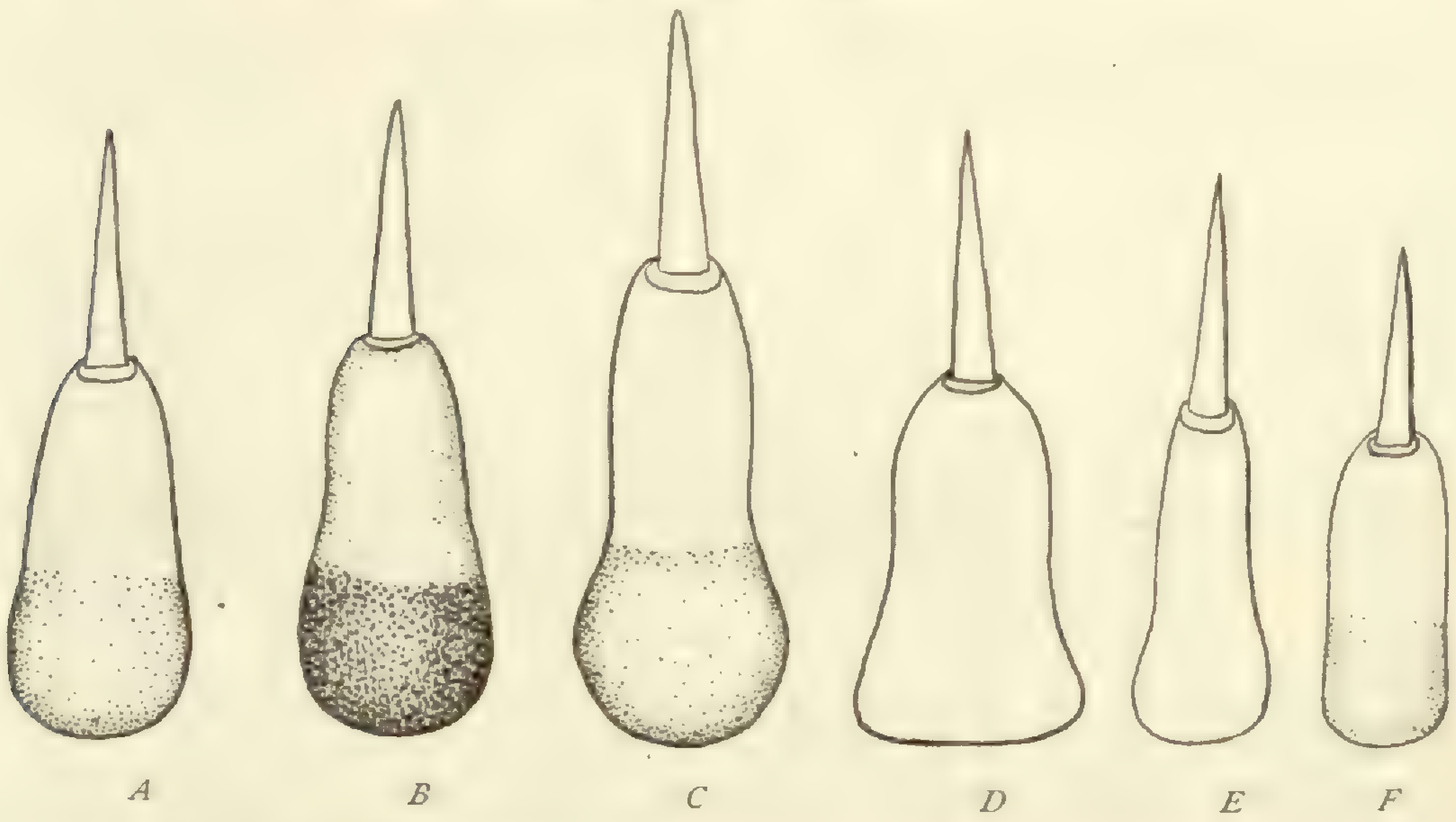


FIG. 9.—Outline of central stylet and bases.
A, *Tetrastemma signifer*.
B and *C*, *T. nigrifrons*.
D, *T. quadrilineatum*.
E, *T. albidum*.
F, *T. reticulatum*.

Usually 20 to 70 mm. in length: head provided with two pairs of very conspicuous, lateral, oblique furrows. Color very variable, except head which is white with shield-shaped or triangular marking of deep brown color on dorsal surface. Body deep purple, deep brown with white dorsal longitudinal band, reddish with brown flecks, pale brownish, or buff on dorsal surface; of similar color, but paler, and often with white longitudinal band, on ventral surface . . *T. nigrifrons* Coe, C.

8. Flesh-color or yellowish, mottled, especially on dorsal surface, with brownish blotches and dots of various shades, often mainly collected into a series of transverse bands; body slender, 8 to 15 mm. in length

T. (*Œrstedia*) *dorsale* (Abildgaard) McIntosh, C, X, Y.

8. White, with large, rectangular and longitudinal, dark brown markings almost covering dorsal surface; often with 16 pairs of rectangular marks and pair of lateral brown lines in addition to bilobed marking on dorsal surface of head; in some varieties markings fuse together; body slender, 8 to 15 mm. in length

T. (*Œrstedia*) *reticulatum* Coe, S.

9. With four groups of fragmented ocelli.

Body usually less than 12 mm. in length; pale yellow; 12 proboscidial nerves . . . . *T. aberrans* Coe, A.

9. Ocelli wanting; hermaphroditic.

Body 5 to 10 mm. in length; whitish or very pale yellowish; probably parasitic in Tunicates . . . . . *T. cæcum* Coe, A.

DREPANOPHORUS.

Ocelli numerous, of very large size; length of body 5 to 10 cm.: dorsal surface dull reddish or orange, thickly covered with fine brownish dots; ventral surface flesh-color with tinge of orange

D. ritteri Coe, S′, 50–150.

PLANKTONEMERTES.

Body broad, much flattened, gelatinous and hyaline; intestinal diverticula numerous; median dorsal vessel present; length 14 to 47 mm.: orange or pink . . . . . *P. agassizii* Woodworth, E (surface).

NECTONEMERTES.

Professor Heath of Stanford University informs me that a species of this remarkable genus has very recently been collected in Monterey Bay, California. Its specific diagnosis has not yet been published.

Order **Bdellonemertea**.

Sucking disk present at posterior end of body; intestine coiled, without cæcum or lateral diverticula; parasitic in various species of pelecypods

MALACOBDELLA.

A single species of this genus has been recorded from California, but it has not yet been studied sufficiently to determine whether it is identical either with *M. grossa* of the eastern coast of North America and Europe or with *M. japonica* of Japan.

LITERATURE.

Although the number of species recorded from this region is so large they are all described in the following papers: —

BÜRGER, O.

'**93**. Südgeorgische und andere exotische Nemertinen. *Zoöl. Jahrb.*, *Abth. Syst.*, vol. 7, pp. 207–240.

(Describes *Tæniosoma* (*Eupolia*) *mexicana* from the west coast of Mexico.)

COE, W. R.

:**01**. Papers from the Harriman Alaska Expedition, XX, The Nemerteans. *Proc. Washington Acad. Sci.*, vol. 3, pp. 1–110, pls. 1–13. Reprinted with the same pagination and plates in the *Harriman Alaska Expedition*, XI, 1904.

(Contains detailed descriptions of 32 species, 23 of which are illustrated by colored figures. Nearly all have full descriptions of anatomical peculiarities. There are several plates of anatomical details.)

COE, W. R.

:**04**. Nemerteans of the Pacific Coast of North America, Part II. *Harriman Alaska Expedition*, XI, pp. 111–220, pls. 14–22.

(In this paper 21 species are enumerated in addition to those mentioned in the first portion of the report. These were collected mainly on the coast of California. Some 18 species are described as new to science, all except one of which are illustrated by colored figures.)

COE, W. R.

:**05**. Nemerteans of the West and Northwest Coasts of North America. *Bull. Mus. Comp. Zoöl.*, vol. 47, pp. 1–318, pls. 1–25.

(This report presents the results of a study of numerous collections made along the whole west and northwest coasts, from Panama to the Arctic Ocean, and in the deeper waters off the shore to a depth of several hundred fathoms. Some 27 species are recorded as new to the region, of which 24 are believed to be new to science. This brings the total number of Nemerteans thus far described from this region to 85, of each of which the more important external features and anatomical peculiarities are described. There are synoptic keys to genera and species, chapters on each of the organ-systems of the Nemerteans, their development, geographical distribution, systematic position, etc. There are 3 colored plates and 22 plates of anatomical structures.)

GRIFFIN, B. B.

'**98**. Some Nemerteans of Puget Sound and Alaska. *Ann. New York Acad. Sci.*, vol. 11, pp. 193–217.

(A posthumous paper containing brief diagnoses of 12 named species.)

PUNNETT, R. C.

:01. Arctic Nemerteans. *Proc. Zoöl. Soc. London*, 1901, pp. 90–107, pls. 6–7.

(Contains a description of one species, *Amphiporus paulinus*, from the Pribilof Islands, and mentions one other from the Commander Islands.)

STIMPSON, W.

'57. *Proc. Acad. Nat. Sci. Phila.*, 1857, pp. 159–165.

(Three species recorded from Pacific coast.)

WOODWORTH, W. McM.

'99. Preliminary Account of *Planktonemertes agassizii*, a New Pelagic Nemertean. *Bull. Mus. Comp. Zoöl.*, vol. 35, pp. 1–4, pl. 1.

In addition to the papers mentioned above, which contain records of the species found on the Pacific coast, many of the species which occur both there and in other regions are described and figured in Bürger's *Monograph of the Nemerteans of the Gulf of Naples*, in Joubin's monograph in the *Fauna Française*, in McIntosh's *British Annelids*, in Verrill's monograph of the New England Nemerteans in the *Transactions of the Connecticut Academy*, and in other well known works.

SHEFFIELD SCIENTIFIC SCHOOL
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STUDIES ON THE PLANT CELL.—VI.

BRADLEY MOORE DAVIS.

Section V. Cell Activities at Critical Periods of Ontogeny in Plants.

We shall discuss in this paper the behavior of the protoplasm at a number of critical periods in the life history of plants when the organism passes from one phase to another of a fundamentally different character. At such times great changes take place in the potentialities of the cells which inaugurate the new developments, changes that are generally most conspicuously shown in the structure of the nucleus. Some of the most interesting events of cell and nuclear history take place at these times, as would be expected from the importance of the phenomena. We shall treat the material under the following heads: (1) Gametogenesis, (2) Fertilization, (3) Sporogenesis, (4) Reduction of the Chromosomes, (5) Apogamy, (6) Apospory, (7) Hybridization, (8) Xenia.

1. Gametogenesis.

The events of gametogenesis are clearly known for the higher plants but there is some confusion and almost no detailed information in the accounts of the thallophytes where the nuclei are very small and the details of the mitoses preceding the formation of sexual cells exceedingly difficult of study.

There is complete agreement among all investigators that the mitoses which precede the differentiation of gamete nuclei in spermatophytes, pteridophytes, and bryophytes are typical karyokinetic figures not differing essentially in the behavior of the chromosomes from the mitoses generally characteristic of the gametophyte generation. This information is based upon a

large number of studies of nuclear figures in antheridia and archegonia, the generative cell of the pollen tube and micropylar region of the embryo-sac. There are no reduction phenomena in these higher groups at the period of gametogenesis.

The subject is complicated in some types of spermatophytes where the gametophyte phase is so reduced that the mitoses which precede gametogenesis may follow immediately upon the two mitoses characteristic of sporogenesis or be separated from them by only one or two divisions. For example, it is known in several types of the lily family (Lilium, Tulipa, Fritillaria, Erythronium, etc.) that the two mitoses of sporogenesis (heterotypic and homotypic) are included in the embryo-sac and become a part of that gametophyte history. The third and final mitosis in this history differentiates the egg in the micropylar end of the embryo-sac and is a typical nuclear division. This subject was treated in some detail in Section III of these "Studies" (*Amer. Nat.*, vol. 38, pp. 741–745, 1904). When the mitoses of sporogenesis are not included within the embryo-sac we find almost without exception three typical mitoses preceding the differentiation of the egg in the angiosperms and a very large number in the gymnosperms, and of course in the pteridophytes and bryophytes the whole vegetative period of the gametophyte which is generally green and self-supporting. There are from two to three mitoses in the pollen grain and male gametophyte of the angiosperms before the development of the sperm nuclei and a somewhat larger and more variable number among the gymnosperms. It is necessary at the outset to understand clearly what are the events of gametogenesis in spermatophytes because several authors have carried the phenomena of sporogenesis over into the period of gametogenesis, where it can have no proper place in exact morphology. Such papers will be treated in connection with "Sporogenesis" and "Reduction of the Chromosomes," for they concern primarily these phenomena alone.

Gametogenesis must be considered at present chiefly from our knowledge of the conditions in the higher plants as they furnish almost the only detailed information that we have on the subject. Upon this as a basis we are justified in suggesting

possibilities in the thallophytes which must remain as speculations until investigations have advanced much farther in this difficult field of cell study. The basis of any theories at present must be phylogenetic, a principle that has not been followed in some of the work upon the thallophytes.

Gametogenesis in plants is full of interest because of the sharp differences from the processes of spermatogenesis and oögenesis in animals. In animals the period of gametogenesis is one of unusual activity. After the germ cells are differentiated there follows a period of cell growth, with the peculiar activity termed synapsis, during which the number of chromosomes is reduced to one half the number characteristic of the species. The germ cells emerge from the growth periods as primary spermatocytes or oöcytes which give rise respectively by two successive mitoses to four spermatids or to an egg with its accompanying polar bodies. The gametes have one half the number of chromosomes characteristic of the species, so that the period of gametogenesis is one of chromosome reduction. The character of this process of reduction will be considered when we take up the analogous phenomena in plants after the discussion of sporogenesis. Gametogenesis in plants is in striking contrast to that in animals. In all higher groups (those above the thallophytes) we know that the gametes have the same number of chromosomes as the vegetative cells of the parent plant (gametophyte). There is no reduction of the chromosomes at the time of gametogenesis, that phenomenon taking place at the end of the sporophyte generation with sporogenesis. Also, there are no peculiarities of the mitoses immediately preceding gametogenesis excepting such as concern the development of cilia-bearing organs (blepharoplasts) or slight peculiarities in the form or size of the spindles, for such nuclear figures are frequently different in these particulars from the mitoses in vegetative cells of the gametophyte. The differences concern chiefly the structure of the sperm, and have been described in our account of that structure (*Amer. Nat.*, vol. 38, July and August, p. 576, 1904).

To Strasburger above all others should be given the credit of making clear these important characteristics of gametogene-

sis in plants. Strasburger's paper of 1894 on "The Periodic Reduction of the Number of Chromosomes in the Life History of Living Organisms" (*Annals of Bot.*, vol. 8, p. 281) was the first elaborate presentation of the principles of gametogenesis and reduction phenomena in plants and has become classical as the foundation of the present attitude in botanical science and the basis and stimulus of a large amount of confirmatory research. The matter really crystallized after the discovery that the sporophyte generation of the higher plants possessed nuclei with twice the number of chromosomes characteristic of the gametophyte and that the reduction took place in the spore mother-cell just previous to sporogenesis.

These facts were gradually established by a number of investigations beginning with Strasburger ('84, '88) and Guignard ('84, '85). Guignard ('91) presented the first complete count of the number of chromosomes in the life history of a plant (*Lilium martagon*), determining the reduction period to be in the spore mother-cell, and Overton ('93 a and b) independently reached the same conclusions for the same plant and extended the knowledge of the chromosome count in gametophyte and sporophyte to a number of other types. Overton's paper was important in its suggestiveness for extended research among the higher cryptogams. Other investigations followed shortly in the gymnosperms, pteridophytes, and liverworts, all supporting the view that the nuclei of the sporophyte generation, following the fusion of gamete nuclei, had double the number of chromosomes characteristic of the gametophyte and that the reduction phenomena occurred at the end of the sporophyte generation in the spore mother-cell. The significance of reduction phenomena at sporogenesis must be phylogenetic since it represents a return of the organism at this time to the ancestral gametophyte condition. The details of this literature belong to the account of "Sporogenesis" and "Reduction of the Chromosomes," and will be taken up later. But it is necessary to present the outline at this time to make clear the important fact that no reduction of the chromosomes takes place during gametogenesis in all groups above the thallophytes.

The theories of gametogenesis among the thallophytes rest

upon information which in point of completeness falls very far short of our knowledge of the groups above. Indeed, no forms have been studied with the detail that is known in higher groups chiefly for the reason that the investigator is forced to deal with very small nuclei and mitotic figures whose chromosomes are exceedingly minute and because of various technical difficulties. The theories in general fall into two groups: (1) those which have an obvious basis in attempts to reconcile events with the processes of gametogenesis in animals, and (2) those proceeding from the view that for phylogenetic reasons the periods and phenomena of gametogenesis in the lower plants should correspond with those of the higher.

We may pass over with a few words the early crude attempts to establish structures for plants comparable to the polar bodies of animals. For example at the conclusion of oögenesis in some algæ (*e. g.*, Vaucheria, Œdogonium) a globule of slime is exuded with the opening of the oögonium. It was suggested that such material is thrown off from the egg but we now know that it is not protoplasmic in character but is apparently derived from a softening of the cell wall. Then the ventral canal cell has been compared to a polar body but it seems clear now that all of the canal cells are homologous and a part of what was formerly an extensive gametogenous tissue within the archegonium. Then the small group of cells cut off below the oögonium of the Charales and the fragmented nuclear material in the trichogyne of the red algæ have been compared to substance thrown off from the egg but without any knowledge of the nuclear structure. Finally the nuclear degeneration which is a very conspicuous feature of oögenesis in certain groups whose oogonia are multinucleate (Peronosporales, Saprolegniales, Pelvetia, etc.) has been considered related to reduction phenomena. But the nuclei in all of these forms bear every evidence of being in each type homologous structures whose large numbers have a phylogenetic *raison d'être* and the extensive degeneration is associated with the principles of sexual evolution which tend to conserve protoplasm for the good of a lesser number of gamete nuclei even to the sacrifice of others that are potentially equivalent.

We will now consider the few instances among the thallo-

phytes in which a reduction of the chromosomes is reported just previous to or during gametogenesis. The best known case is Fucus since this type has been studied by three investigators: Farmer and Williams ('98) and Strasburger ('97a). They agree in describing the nuclear figure that differentiates the oögonium from the stalk cell as exhibiting a large number of chromosomes (28 or 30) while the three mitoses within the oögonium, which give rise to the eight eggs, present only one half that number (14 or 15). Apparently there is a reduction by one half just before the mitoses in the oögonium. Since there is no sporophyte generation in Fucus it is of course difficult to compare these conditions with those in higher plants, but, as will be explained later, there are some reasons why we should not expect to find reduction phenomena at gametogenesis in any thallophyte.

Reduction phenomena at gametogenesis have also been suggested for various types of the Peronosporales and Saprolegniales but not, however, in exactly the same way as in Fucus. There are always, as far as is known, one or two mitoses within the oögonium before the gamete nuclei are organized and it has been held that these are reduction divisions by Rosenberg for the Peronosporales and by Trow for the Saprolegniales. Rosenberg (:03b) described for the oögonium of Plasmopara a condition of synapsis in the nuclei preceding the two mitoses and compared this sequence with the events of sporogenesis in higher plants in which the two divisions within the spore mother-cell are preceded by a period of synapsis. Rosenberg did not determine the number of chromosomes in the vegetative nuclei so that he has no positive evidence of reduction in the oögonia. With respect to the two mitoses and the preliminary synapsis I have already pointed out in criticism of Rosenberg's studies (*Bot. Gaz.*, vol. 36, p. 154, 1903) that the number of mitoses is variable in the oögonia of the Peronosporales and Saprolegniales and apparently entirely absent in the species of Vaucheria studied by myself (Davis, :04a). Also, the phenomenon of synapsis, which is easily recognized in the large nuclei of the spore mother-cell, would be difficult to establish in the small nuclei within the oögonia of the forms mentioned above. Nuclei can be found

in a number of structures with their contents somewhat massed at one side or in the center but such conditions must not be confused with the remarkable process of synapsis in the spore mother-cell. Among all the excellent studies of gametogenesis in the Peronosporales I cannot find any clear evidence of a reduction of the chromosomes at gametogenesis.

Quite different is the account that Trow (:04) brings forward to support his view of chromosome reduction during gametogenesis in the Saprolegniales. Trow describes two mitoses in the oogonium of *Achlya debaryana*; in the first the number of chromosomes is eight which becomes reduced to four in the second. Trow's account of a second mitosis in Achlya is very different in a number of particulars from the results of all investigations on gametogenesis in the Peronosporales and Saprolegniales. Two centrosomes with radiations are said to appear at the poles of the spindle at anaphase, structures which were not present in the first mitosis. Some of these asters become the center of the egg origins and are later accompanied by deeply staining material constituting a body which Trow terms an ovocentrum and which perhaps corresponds to a coenocentrum. Relatively few of the nuclei in the oogonium are said to pass through this second mitosis and some of their products, with the accompanying asters, break down. The remainder become the functional gamete nuclei of the eggs. There are many complex activities described by Trow in connection with the appearance of the asters during the second mitosis and also at the side of the sperm nuclei which are said to enter the oogonium, events that cannot be correlated with the processes of gametogenesis and fertilization as we understand them for the Peronosporales. They are treated briefly in a review by myself (*Bot. Gaz.*, vol. 39, p. 61, 1905), where, however, I misunderstood a distinction that Trow draws between the aster and the ovocentrum (see an answer by Trow, *Bot. Gaz.*, vol. 39, p. 300, 1905). My impression is that either Trow has been mistaken in his interpretations or that there are present events which must entirely change our conception of gametogenesis in the Saprolegniales and Peronosporales, but which are not fully explained by Trow's paper.

Let us now think of gametogenesis among the thallophytes

with reference to what we know of the process in higher groups and the principles of the origin and evolution of sex and the sporophyte among the lower. It seems clear that the sporophyte generation is characterized by a double number of chromosomes as a result of the fusion of gamete nuclei at fertilization. We must then lay the fundamental inception or origin of the sporophyte to the stimulus of the sexual act. That is, the sexually formed fusion cell must have different potentialities from the germ plasm of the parent gametophyte and it cannot produce a gametophyte again until these potentialities are worked off and the protoplasm returns to the dead level of the ancestral stock (the gametophyte). By the potentialities of the sporophyte plasm we mean primarily a greater energy or growth stimulus which must express itself differently from the gametophyte. Morphologically we can only distinguish sporophyte plasm from gametophyte plasm by the double number of the chromosomes but of course the complexities of the sexual act would make great differences in the chemical structure of the two. The divergences in the history of the gametophyte and sporophyte, as shown throughout ontogeny and phylogeny, are but the final expressions of the different potentialities of the protoplasm in each generation. The morphological forms of expression of the sporophyte are extraordinarily various and in the long evolutionary history of this generation have developed great structural differentiation but with every life history the sporophyte has the same beginning (fertilization, with the doubling of the chromosomes) and the same ending (sporogenesis, with chromosome reduction). Between the beginning and the end is intercalated a vegetative period, short and simple in some forms, and very long and elaborate in others. The history of the development of this vegetative period or the evolution of the sporophyte is a subject far outside of and secondary to the scope of this discussion. We are only concerned with the protoplasmic activities at the beginning (fertilization) and the end (sporogenesis) of the sporophyte generation.

We know nothing of the behavior of the chromosomes in types of the thallophytes which illustrate most closely our conception of the origin of sex and of the sporophyte generation.

I refer to many lower algæ such as Ulothrix, forms of the Volvocaceæ, Œdogonium, Coleochæte, and many others. However, the homologies of primitive gametes and their origin from types of asexual zoöspores is very clear in a number of groups. We can see nothing in the morphology and mode of development of these reproductive cells to suggest reduction phenomena when gametes are produced. The primitive gamete is generally somewhat smaller than its homologue the zoöspore, often because the protoplasm of the gamete mother-cell becomes distributed in a greater number of daughter elements. It is well known that the conditions that lead to conjugation are exceedingly variable, depending upon environmental factors and one often cannot tell at the time whether a swarm spore will show sexual habits or germinate without conjugation. The most satisfactory theory of the origin of sex in plants regards primitive gametes as weaker or lacking in certain potentialities of vegetative growth and the conjugation as a mutually coöperative process resulting in a rejuvenescence of the protoplasm. The fact that many simple types of gametes will germinate without fertilization and produce small and weak sporelings shows that vegetative possibilities are not entirely lost. Investigations on the chromosome history among these forms, difficult though they be, are some of the most interesting subjects of botanical research. We know some general principles of the origin and evolution of sex in plants (Davis, :01b, :03a) but of the chromosome history in the simplest types of gametogenesis nothing is known.

With respect to the history of the chromosomes in the simplest sporophytes we are also as ignorant as in the simplest types of gametogenesis. We have excellent reasons for believing that the sporophyte generation is represented among the thallophytes in a number of very simple conditions. Numbers of zygospores and oöspores (*e. g.*, Ulothrix, Œdogonium, forms of the Conjugales and Volvocaceæ, etc.) give rise on germination to several daughter cells. In higher forms this growth period is lengthened to the formation of a reproductive tissue (Coleochæte) and in the great groups of the Rhodophyceæ, Ascomycetes, and Basidiomycetes there is present an extensive development from the fertilized female cell (or its equivalent when apogamy obtains)

involving the development of a vegetative structure before the period of sporogenesis. From the studies of Wolfe (:04) we know that the sporophyte portion of Nemalion (the cystocarp) contains nuclei with double the number of chromosomes (about 16) present in the gametophyte (about 8) and that the period of chromosome reduction is apparently just previous to the development of the carpospores (sporogenesis). Williams (:04a and b) has recently determined that the asexual plant of Dictyota is a sporophyte generation with double the number of chromosomes (32) found in the sexual plant (16). The reduction occurs here during a rather long period of preparation on the part of the nucleus in the tetraspore mother-cell and the reduced number appears in the two mitoses that form the tetraspores. These events closely parallel those in the spore mother-cell of higher plants and will be discussed further under "Sporogenesis."

William's (:04b) account of gametogenesis in Dictyota is the most complete that we have for any thallophyte. The oögonia and antheridia are cut off from a stalk cell by a mitosis which presents 16 chromosomes, the number characteristic of the gametophyte. The contents of the oögonium forms a single egg and consequently presents no mitotic phenomena. The antheridium develops over 1500 sperms thus exhibiting a large number of successive divisions. These all show 16 chromosomes and the mitoses are typical, not differing in any essential from the division in the stalk cell. The entire absence of mitoses in the oögonium and the great number in the antheridium are striking facts which show that no especial significance can be attached to nuclear divisions within sexual organs of this type. There is no place for reduction phenomena within these sexual organs and none precede their development.

These studies of Williams and Wolfe justify us in expecting that other thallophytes will support their discoveries that the product of the sexual act will have a fusion nucleus with double the number of chromosomes present in the sexual plant (gametophyte) and that reduction phenomena may be expected to follow the sexual act and not precede it as in animals. In such thallophytes as have no sporophyte generation we may suppose, as Strasburger ('94a) suggested, that the number of chromo-

somes is reduced with the germination of the sexually formed cell so that the protoplasm returns at once to the potentialities of the gametophyte. It is quite possible that the four zoöspores produced from the oöspore of Œdogonium and the four nuclei found in the germinating zygospores of the desmids and Spirogyra may indicate divisions concerned with reduction phenomena similar to those in the tetraspore mother-cells of Dictyota (which may also be expected in the tetraspore mother-cell of the red algæ) and in the spore mother-cell of the higher plants.

For these reasons we seem to be justified in taking a critical attitude towards the accounts of chromosome reduction at gametogenesis among the thallophytes. The logic of the situation would lead us to expect that every sexual act gives a doubling of the chromosomes and an impulse towards the development of a sporophyte phase in plants which must be worked off before the protoplasm is in condition to reproduce the parent gametophyte. Reduction phenomena should follow then every sexual act. If it takes place immediately with the germination of the sexually formed cell there is of course no sporophyte generation. Because the conception of the sporophyte generation with reduction of the chromosomes at sporogenesis is so clearly established in higher groups, those investigators who claim reduction phenomena at gametogenesis must expect their views to be severely scrutinized and accept the responsibility of presenting very clear and convincing proof of their conclusions. The author does not think that this evidence is supplied in satisfactory form by any investigation so far.

2. Fertilization.

In Section IV of these "Studies" we described the most important phenomena of fertilization under the caption "Sexual Cell Unions and Nuclear Fusions." It will not be necessary to discuss the facts of the phenomena in detail again. This account will take up the more theoretical aspects of the events of fertilization and their relation to other critical periods of ontogeny.

Plants are in complete agreement with animals in the follow-

ing chief events and principles of fertilization. Thus Van Beneden's conclusion of 1883 that sexual nuclei are equivalent in their chromatin content at the time of fusion irrespective of differences in size is admirably borne out by Miss Ferguson's (:04) studies on the pine. In this form as in the gymnosperms generally the male nucleus is much smaller than the female and comes to lie in a depression in the latter before the actual fusion takes place. After the fusion the paternal and maternal chromosomes are found in two groups side by side preparatory to the first cleavage mitosis and are indistinguishable except for their position; the chromatin of the two sexes is equal in amount as far as can be seen. Then the observations of the Hertwig brothers, in 1887, and Boveri, in 1889 and 1895, that the sperm nucleus could enter and cause the development of denucleated eggs or their fragments thus taking the part of a female nucleus in parthenogenesis, were established for plants by Winkler's (:01) experiments on Cystoseira. Winkler was able to divide the egg of this brown alga into a nucleated and a non-nucleated portion and he found that sperms entered the non-nucleated parts and caused them to develop sporelings side by side with the fertilized nucleated portions. The sporelings from the non-nucleated fragments, controlled by the sperm nuclei alone, developed about half as rapidly as those from the originally nucleated portions which of course were dominated by sexually formed fusion nuclei, but the two sets of sporelings were alike in form as far as they were grown. Only with respect to Boveri's celebrated theory that the sperm brings to the egg in the centrosome the mechanism of cell division, do plants fail to support the conclusions of certain zoölogists with respect to the most important events of fertilization. This point upon which zoölogists are not in full accord will be discussed later. There is general agreement in the view that the male nucleus of plants supplies chromosomes equal in number and equivalent quantitatively to the female, and general accord in the conclusions that the chromosomes by their individuality, apparent permanence of structure, and fixed behavior must be bearers of hereditary characters.

Evidence from the most recent investigations upon favorable forms of both animals and plants indicates that the chromosomes

from both gametes maintain their independence and never fuse at the immediate time of fertilization. We have reason to assume, chiefly from zoölogical studies, that the paternal and maternal chromosomes of plants remain independent throughout the entire sporophyte generation and that no fusion takes place until the period of chromosome reduction at sporogenesis. If no sporophyte generation is present we should expect the fusion and reduction of the chromosomes to occur after the sexually formed cell had passed through a period of rest (for all reduction phenomena seem to require considerable time) unless there be actually such reduction during gametogenesis in the thallophytes as reported for Fucus and Saprolegnia. The morphology of the chromosomes is probably unchanged by the immediate act of fertilization. The fusion nucleus simply contains double the number of chromosomes present in each gamete nucleus which increases by so much the metabolic possibilities which lie in these structures.

Besides chromatin the sperm brings into the egg a certain amount of cytoplasm. Some of this may be the substance of the blepharoplast or other kinoplasm associated with the nucleus but there is often besides considerable granular trophoplasm, sometimes with inclusions of starch and other food substances, and the male gamete of certain thallophytes contains a chromatophore. There is no reason to suppose that development especially characteristic of fertilization, the sporophyte generation, has any relation to this trophoplasm with its food inclusions, excepting as it may stimulate growth which is to be expected whenever organic food material is introduced into protoplasm. But we can hardly believe that the formative elements or the rudiments of further development especially those of a sporophytic character lie in this region of the protoplasm. They must be sought in the nuclei and in the only stable elements of the nuclei, the chromosomes.

It has been held at times by botanists, following the lead of certain zoölogists, that the sperm or sperm nucleus introduced a centrosome into the egg which organized the first cleavage-spindle and thereby played a necessary part in starting cell division. Such a centrosome would naturally be sought in the

blepharoplast which is clearly analogous to the middle piece of the animal spermatozoön. We have no evidence that such events ever take place in the eggs of plants. On the contrary we know that the first cleavage-spindle in the eggs of spermatophytes develops without centrosomes from a mesh of fibrillæ. Also the blepharoplasts of the gymnosperms Cycas, Zamia, and Ginkgo remain in the cytoplasm at a distance from the fusion nucleus and Shaw's account of the fern, Onoclea, indicates that similar conditions obtain there. We know less about the history of the blepharoplasts within the egg of thallophytes where the first cleavage-spindle frequently has very handsome centrospheres and asters (*e. g.*, Fucus and Dictyota). Strasburger ('97a) pointed out that one of the asters of the first cleavage-spindle in Fucus arose near the point where the male nucleus united with the female. However, Farmer and Williams ('98) believe that centrospheres of the first cleavage-spindle in Fucus are formed *de novo* and Williams (:04b) came to the same conclusion for Dictyota. There are some very interesting features in the comparative study that Williams (:04b) has made on the development of the first segmentation spindle in the fertilized and parthenogenetic eggs of Dictyota. The spindle in the parthenogenetic egg is multipolar and develops from an intranuclear kinoplasmic mesh and there are no centrospheres. But in the fertilized egg a centrosphere always appears at the side of the nucleus and apparently divides into two which separate until they lie at opposite poles of the mature spindle. Yet Williams after a very careful study concludes that this centrosphere arises *de novo* and believes that the stimulus of fertilization enables the fusion nucleus to form a centrosphere external to itself, a thing which is not possible for the nucleus of the parthenogenetic egg.

It seems then probable that the only structures of the sperm that preserve their morphological entity in the fertilized eggs of plants are the chromosomes. Whatever may be the relation of the blepharoplast and other cytoplasmic structures as stimuli to the development of the egg they cannot be regarded as fixed factors in the problem of heredity. It is very probable that they introduce valuable food material, perhaps important fer-

ments, substances of great service, although possibly not absolutely necessary to the successive metabolic processes which characterize growth and development. But the fact remains that we have in the chromosomes the only new morphological elements. And the progress of research seems ever to strengthen the general view that in the chromosomes are contained the directive rudiments of development and that they are the bearers of hereditary principles. Nuclear studies on apogamous forms will certainly prove of great interest in this connection. We have reason to expect some very important results from thorough cell studies on apogamy and apospory.

The best developed theory of fertilization in plants is that of Strasburger and a statement of his views should precede any comments of other authors. Strasburger has written much on the phenomena of fertilization ; important considerations may be found in his papers of '94a, b, '97c, :00a, b, :01, and :04a. Strasburger points out that the protoplasm of the egg is predominately trophoplasmic in character because of the proportionately very large amount of cytoplasm with granular inclusions that are evidently food material or the products of metabolism. On the other hand the cytoplasm of the sperm contains relatively little trophoplasm and much kinoplasm, especially when the sperm is a ciliated cell with a large blepharoplast. As Strasburger conceives kinoplasm to be the active substance of spindle formation, he concludes that the sperm might bring to the well nourished egg, rich in trophoplasm, the substance necessary to start the mechanism of mitosis. In its broad aspects this view is very similar to the celebrated theory of Boveri, 1887, that the spermatozoön supplied the animal egg with the centrosome which is conceived as necessary to start mitotic processes and that the egg is powerless to divide before fertilization because it lacks such a structure.

Another feature of Strasburger's views (advanced in his paper of :00b) appears to have grown out of the discovery of the so called "double fertilization" in the embryo-sac and other nuclear fusions whose sexual significance is not clear, together with the phenomena of parthenogenesis as produced experimentally in many studies of recent years. Strasburger considers that two

processes are involved in the sexual act. The first, termed "vegetative fertilization," is simply the stimulus to growth which results from the fusion of two nuclei or other masses of protoplasm. The second, called "generative fertilization," involves deeper factors than those of mere growth stimulus. These lie in the union of germ plasm of diverse parentage with the mingling of hereditary racial characters and individual variations and the establishment of a new organism which may have possibilities of development quite different from the parent form. The effects of "vegetative fertilization" may be imparted to protoplasm artificially by chemical and physical stimuli as has been done in the numerous experiments of Klebs and Loeb on the conditions which induce parthenogenetic development. "Generative fertilization" has a phylogenetic significance and a background which is entirely apart from the mere vegetative processes of cell growth and division.

It is apparent that Strasburger's theory is open to the same line of criticism that has been brought against the universal application of Boveri's hypothesis that the spermatozoön brings to the egg the agent of cell division as a centrosome. The investigations of several zoölogists indicate that one or both of the centrosomes in the first cleavage-spindle may be derived from the egg or may be formed *de novo* (see Wilson, :00, pp. 196, 208). The kinoplasm of the plant sperm, whether in the form of a blepharoplast or as an ill defined accompaniment of the sperm nucleus has not been shown to take part in the formation of the first cleavage spindle. There is no evidence that the blepharoplast retains its organic entity in the egg to pass over into a centrosome or centrosphere. Of course the kinoplasm which lies immediately without the nuclear membrane of the sperm, and there is sometimes a conspicuous amount of this densely granular protoplasm, must merge with similar kinoplasm associated with the egg nucleus at the time of fusion. For example Miss Robertson (:04) and Coulter and Land (:05) note in Torreya that the sperm nucleus brings to that of the egg a large amount of accompanying kinoplasm which forms an investing layer around the fusion nucleus. It is reasonable to suppose that the mixing of these masses of kinoplasm with the

fusion of the gamete nuclei would give material for a larger and more highly differentiated nuclear figure in the first cleavage of the egg.

Williams' (:04b) observations and conclusions on Dictyota are especially interesting in this connection for he shows that the first cleavage-spindles in the parthenogenetic eggs are intranuclear and multipolar, showing no dominant kinoplasmic centers while the fertilized eggs form each a well differentiated centrosphere with radiations, exterior to the nuclear membrane, which clearly guides the whole process of spindle formation. Williams does not hold that this centrosphere comes as an organized structure from either sperm or egg but is developed *de novo* by the fusion nucleus as the result of the general stimulus of fertilization. The evidence, then, furnished by studies on fertilization in plants, indicates that the chromosomes alone maintain morphological independence throughout the process of fertilization and that the kinoplasmic (archoplasmic) elements play no part in the phenomena as fixed morphological structures but simply contribute their substance to the general union of cytoplasm with cytoplasm, and that any specialized kinoplasmic structures of the first cleavage spindle are formed *de novo*. While it is true that the sperm brings to the egg much kinoplasm it may well be questioned whether such kinoplasm is a necessary factor in the formation of the first cleavage-spindle. It seems more probable that the development of achromatic structures in the first mitosis following fertilization is due rather to the general stimulus of cell and nuclear fusion than to particular structures supplied by either sperm or egg.

The second phase of Strasburger's theory of fertilization concerns a separation of the two processes in the sexual act: (1) the mere growth stimulus, "vegetative fertilization," that may be expected with the union of any two masses of protoplasm, and (2) the clearly defined sexual phenomena, "generative fertilization," which lies in the union of germ plasm of different parentage and diverse potentialities and which leads to the inheritance of these characteristics. It seems clear that the two processes are really present and can be clearly distinguished. But it may be strongly questioned whether the factors charac-

terizing the first (vegetative fertilization) should really be considered a part of the sexual act. Strasburger regards the processes of "generative fertilization" as essential to the sexual act. The growth stimulus "vegetative fertilization" is always to be expected as an accompaniment of fertilization. It may be given to cells in other ways than by the sexual act and is found in cell and nuclear fusions which for phylogenetic reasons are plainly not sexual.

The experimental work of recent years on the conditions determining artificial parthenogenesis have done much to define the sorts of factors which stimulate growth and division of sexual cells when the process of fertilization is suppressed. Klebs for plants and Loeb for animals have been foremost in these studies and they have shown that what seem to be very minor changes in the environment of the sexual cell may suffice to give a gamete the power of immediate development without fertilization. Thus the egg of the sea urchin will develop parthenogenetically to an advanced stage when placed for a short time in sea water containing magnesium chloride and then brought back to normal sea water. Nathansohn (: 00) found that a small proportion (about 7 %) of the eggs of *Marsilia vestita* would germinate parthenogenetically when the megaspores were cultivated for 24 hours at the rather high temperature of 35° C. and then left to continue their development at 27° C. There are then a number of factors such as varying osmotic pressure, temperature, and in some cases chemical reagents which may induce gametes to further development without the usual sexual processes. These reactions seem to be of a similar character to the processes in that phase of sexual reproduction termed "vegetative fertilization" by Strasburger. They give the stimulus to growth but without that essential feature of sexuality, the mingling of germ plasm of different parentage which distinguishes the processes of "generative fertilization."

It seems to the author, for the sake of clearness, that we are trying to include too much under the term fertilization. If the features of "vegetative fertilization," *i. e.*, the growth stimulus, can be introduced experimentally as in artificial parthenogenesis then they cease to be fundamental qualities of the sexual act.

They are accompaniments of sexual processes which may always be expected but nevertheless are not the essential characteristics. The essence of the sexual act (fertilization) is the union of germ plasm with such possibilities of new developments as come from the inheritance of mixed characters from two lines of ancestry. And the more diverse and complex are the characters of the parents the more conspicuous are the essential features of the sexual act. Among lowly organisms and in simpler types of sexual processes the growth stimulus becomes exaggerated in our attention because the features of heredity are not so prominent as in the higher forms. But in the higher groups the varied characters of offspring express clearly the subtle factors concerned with the mingling of diverse germ plasm in the process of fertilization and the growth stimulus recedes into the background.

For these reasons it seems to me that the term fertilization should only be used for the mingling of germ plasm with the possibilities of new combinations in the potentialities of the resulting sexually formed cell and that the growth stimulus should be treated as an accompaniment but quite apart from the essentials of the sexual act. And for these reasons I was careful to include in Section IV under the caption "Sexual Cell Unions and Nuclear Fusions" only illustrations in which the sexual nature of the phenomena was clearly shown by applying a morphological or phylogenetic test to the elements concerned in the process of cell fusion. The phylogenetic test seems to me the only sure way of determining the sexual nature of the members of a cell fusion and there are very few cases in which there can be any hesitation in deciding whether or not such elements are morphologically gametes.

I included under "Asexual Cell Unions and Nuclear Fusions" in Section IV a number of cases in which the sexual nature of the act is under dispute for the reason that none of these satisfy the phylogenetic test. It is perfectly clear that the growth stimulus is a conspicuous feature of these cell and nuclear fusions, and that in this feature they resemble sexual processes but this does not, to my mind, make them acts of fertilization or the equivalent of sexual processes. The union of sporidia in the

smuts and of yeast cells, the fusion of nuclei in the teleutospore and basidium and in the apogamous development of ferns, the double fusion of polar nuclei and multiple nuclear fusions in the embryo-sac (Corydalis) illustrate phenomena which I cannot regard as sexual even though they have in them elements associated with sexual processes and in certain cases may be substitutes for a former sexual act. In none of these instances can we be positive that the nuclei concerned are morphologically and phylogenetically gamete nuclei. This point was discussed in some detail in Section IV. It seems to me that Blackman's (:04 a, p. 353) conception of the cell fusions preceding the æcidium in Phragmidium as "reduced forms of ordinary fertilization" or Farmer's (:03) explanation of apogamy in the fern "as a kind of irregular fertilization" leads to a confusion of a substitute process with a true sexual act. The substitute processes have their true place as phenomena of apogamy. They can, however, only have a sexual significance if they represent the origin of a new set of gametes in the organism, a proposition which is not likely to be maintained by anyone.

3. Sporogenesis.

We are employing the term sporogenesis, as must have been apparent in preceding divisions of this paper, to designate a characteristic and highly specialized type of spore formation that is universal in all plants above the thallophytes. The process always terminates the sporophyte phase in ontogeny of these higher plants, and is especially distinguished as the period of chromosome reduction in the life history. The cell activities of sporogenesis are therefore of particular interest, and, since spore mother-cells are generally large and their nuclear and cytoplasmic structure especially clearly differentiated, we have perhaps obtained more knowledge of mitotic phenomena from the study of these elements than of any other tissues of the plant body.

The reduction phenomena of sporogenesis have been established in some forms of the thallophytes, certainly in the tetraspore mother-cell of Dictyota (Williams, :04a). There are also reasons for suspecting that the oöspore of Œdogonium and the

zygospores of Conjugales on germinating present similar events. The teleutospore and basidium are probably also the seat of chromatin reduction (Blackman, :04b) in the formation of spores either directly or through the promycelium. The ascus holds a position at the end of a sporophyte phase which suggests a similar relation in this group of fungi. Chromosome reduction may also be expected in the tetraspore mother-cell of the Rhodophyceæ, as in Dictyota, but this subject has never been investigated. There are occasional red algæ in which the tetraspores are sometimes borne on the same plant with the sexual organs, conditions which may be difficult to explain on the theory that the tetrasporic plant is a sporophyte. Thus *Spermothamnion turneri* on the American coast frequently bears both procarps and tetraspores on the same plant, and I have also seen cystocarpic plants of *Ceramium rubrum* some of whose branches contained tetraspores. Lotsy (:04a) also reports similar conditions in *Chylocladia kaliformis*. The other extremely varied methods of spore formation (zoöspores, conidia, etc.) in the thallophytes do not concern the present discussion. They seem to have no fixed place in the life history and there is nothing to indicate any relation to reduction phenomena, although we actually know nothing about the chromosome history among these lowly forms.

The importance of sporogenesis as a critical period in the life history of higher plants became at once apparent with the discovery that fertilization doubled the number of chromosomes in the nuclei of the sporophyte phase and that the double number was reduced during sporogenesis. As stated in our account of gametogenesis, these facts were first established for a number of spermatophytes by the work of Strasburger ('84, '88, and '94), Guignard ('84, '85, and '91), and Overton ('93 a and b). Guignard ('91) presented for *Lilium martagon* the first complete account of the number of chromosomes in the life history of a plant, and his results were also established independently by Overton ('93 a and b). Then followed confirmatory investigations among the bryophytes in the work of Farmer ('94, '95 a, b, c) and in the pteridophytes by Strasburger ('94, p. 294) for Osmunda. Since 1895 the investigations among the spermatophytes have so multiplied that we know the number of chromo-

somes in sporophyte and gametophyte for more than fifty forms. This list may be found in Coulter and Chamberlain's recent text-book, *The Morphology of the Angiosperms*, 1903, p. 81. Farmer's accounts of the number of chromosomes in the Hepaticæ have been confirmed and extended by myself (Davis, '99, :01a) and by Moore (:03). The more recent literature, especially as it concerns the events of spindle formation in the mitoses characteristic of sporogenesis has been treated in our account of the spore mother-cell (*Amer. Nat.*, vol. 38, p. 725, Oct., 1904).

There are two chief periods in the processes of sporogenesis as illustrated in all groups above the thallophytes: (1) a growth period and (2) a period of cell division. In the growth period the spore mother-cells become differentiated from the general sporogenous tissues through a great increase in the amount of protoplasmic material. At some time in this growth period the nucleus of the spore mother-cell exhibits the phenomenon of synapsis, a very characteristic event, recognized by the very much contracted condition of the chromatin network in the interior of the nucleus. Synapsis is believed to hold fundamental relations to reduction phenomena as the time when chromosomes unite with one another in pairs. The period of cell division follows synapsis and is characterized by two mitoses in the spore mother-cell, the second following immediately upon the first, and a segmentation of the protoplasm, sometimes by two successive divisions, and sometimes by a simultaneous cleavage, into four spores. The two mitoses present certain peculiarities in the structure and behavior of their chromosomes which are unlike the events of typical mitoses. The first is known as the heterotypic and the second as the homotypic mitosis. These peculiarities have been recognized for a long time and have furnished the subject of much investigation and contradictory explanations. They were briefly described in Section III (*Amer. Nat.*, vol. 38, p. 740, Oct., 1904) but recent studies of Farmer and Moore (:03, :05) have opened again a discussion which seemed closed at that time. The details of synapsis and the heterotypic and homotypic mitoses will be taken up under the caption, "Reduction of the Chromosomes."

Contrary to a statement in Section III of these studies (*Amer.

Nat., vol. 38, p. 726, Oct., 1904) there is probably a deep significance in the fact that two mitoses are almost universally present in the spore mother-cell so that four spores are formed. It is probable that these mitoses are always heterotypic and homotypic, although this fact has only been clearly established in comparatively few favorable forms, and that they are indispensable to the mechanism of reduction phenomena. The latest accounts describe the first mitosis as the separation of the two portions of a bivalent chromosome, that is of two chromosomes joined either side by side or end to end, giving it a unique position among the mitoses of the life history. According to these theories the two mitoses of sporogenesis are features of a remarkable mechanism by which the paternal and maternal chromatin after its union in synapsis may become distributed in proportions that can be expressed by mathematical ratios. The peculiarities of the homotypic mitosis depend on a premature fission of the daughter chromosomes of the heterotypic division as will be explained in the next portion of this section. Thus the four spores are the result of these peculiar mitoses and have morphological significance. We are even justified in suspecting that the groups of four spores when found in the thallophytes, as the tetraspores of Dictyota and the red algæ, the four spores formed on the basidium and promycelium and the four spores of nuclei present in the germinating oöspore and zygospore of Œdogonium and the Conjugales indicate the presence of reduction phenomena simply because the number four is so constant. Williams (:04a) for Dictyota and Blackman (:04b) for types of the Uredinales have discovered clear cytological evidence of this reduction phenomenon but we know nothing of the chromosome history in other types.

We have already referred to the fact (Section III, *Amer. Nat.*, vol. 38, p. 743, Oct., 1904), that in the spermatophytes the two mitoses characteristic of sporogenesis are very close to the mitoses which differentiate the gamete nuclei. In the male gametophyte of the Angiosperms there are generally only two mitoses between the events of sporogenesis and gametogenesis and in gymnosperms there is a somewhat larger and variable number. The female gametophyte of the angiosperms usually

presents three mitoses after those of sporogenesis before the egg nucleus is formed. But in a number of types in the lily family (*e. g.*, Lilium, Tulipa, Fritillaria, Erythronium, etc.), the mitoses of sporogenesis are actually included in the embryo-sac and the very next mitosis, which is typical, differentiates the egg (see Section III, *Amer. Nat.*, vol. 38, pp. 741–744, Oct., 1904). This is the furthest point attained in the reduction of the gametophyte which in such forms actually includes but a single nuclear division in its history. But however close the mitoses of sporogenesis come to those of gametogenesis it is perfectly clear through the long phylogenetic history in the lower spermatophytes, pteridophytes, and bryophytes that the two are morphologically distinct processes and are always separate. It is unfortunate that the terms spermatogenesis and oögenesis should be applied to processes of sporogenesis as has been done by several authors, for such usage involves a confusion of two events which phylogeny clearly shows to be different in origin and to have back of them the diverging history of sporophyte and gametophyte from the times of thallophyte ancestry, the most remarkable evolutionary history in the plant kingdom.

It is conceivable that some plants may finally reach a stage in their evolutionary history when all the gametophytic mitoses in the pollen grain and embryo-sac will be suppressed and the nuclei resulting from sporogenesis become gamete nuclei. But it is clear that in such an event the gametophyte phase would be obliterated and we should have an entirely new type of life history. There would then be only one organism (derived from the sporophyte) whose gametes would be formed immediately with the differentiation of the pollen grain and embryo-sac. Such an organism would present reduction phenomena with the differentiation of the gametes and its type of life history would be identical with that of animals. We should look for such a reduced life history in groups related to forms in which the mitoses of sporogensis are included in the embryo-sac and the gametophyte phase is represented by a single nuclear division (*e. g.*, Lilium, Tulipa, Fritillaria, Erythronium, etc.). Search among some of the most highly specialized Monocotyledonæ may actually reveal examples of the complete suppression of the female gametophyte.

The speculative possibilities of a suppression of a sexual generation and the assumption of sexuality by an asexual phase were clearly in the mind of Strasburger when he suggested ('94b, p. 852) the possibility that the two mitoses characteristic of oögenesis and spermatogenesis in animals might signify the remains of a former sexual generation now entirely suppressed in the Metazoa. This suggestion was based on the striking similarity of the events of sporogenesis in plants to those of gametogenesis in animals and on the history of sporogenesis as shown in plant phylogeny. This history is remarkably clear and there can be no question but that the phenomena of sporogenesis have developed as the result of sexual processes and are always associated with an asexual generation (sporophyte). It is also clear that the ancestral primitive sexual generation (gametophyte) has steadily degenerated until now it is almost lost in such embryo-sacs as include the two mitoses of sporogenesis within their history. If the sexual generation should become entirely lost the life history of a higher plant would present the same features with respect to the period of chromosome reduction as that of an animal: there would be but one organism, the homologue of the sporophyte which would produce gamete nuclei with reduction phenomena previous to gametogenesis just as in animals. Several authors have expressed views similar to Strasburger's suggestion ('94b, p. 852) or carried the speculation even farther than he. Beard ('95a, p. 444) along these lines of argument combined with conclusions from Bower's ('87) studies on apospory, announced a belief that "Metazoan development was really bound up with an *antithetic* alternation of generations." Lotsy (:05, p. 117) expresses unequivocally the view that the animal body represents an asexual phase (2x generation) and that the sexual phase (x generation) is confined to the sexual cells. Chamberlain (:05) simultaneously with Lotsy and in much greater detail presents a comparison of the phenomena of sporogenesis in plants with gametogenesis in animals tracing the resemblance in the events of chromosome reduction step by step and states his belief that "animals exhibit an alternation of generation comparable with the alternation so well known in plants."

This is not the place to consider this theory in detail from a

zoölogical standpoint since it bears only indirectly upon the material of these papers. Zoölogists have, however, discussed critically Strasburger's suggestions (see Wilson, :00, p. 275, and Häcker, '98, p. 101). The difficulties of accepting this view of a possible *antithetic* alternation of generations in animals seem insurmountable. In the first place there is not the slightest evidence of *antithetic* alternation of generations in the Metazoa or for that matter anywhere in the animal kingdom. The examples of alternation of generations which the zoölogists present among the Cœlenterates are all illustrations of *homologous* generations derived from buds. There is no indication of spore formation comparable to the process in the higher plants, so far as I am able to judge, in any group of animals. And also there seems to be accumulating evidence of reduction phenomena previous to the development of sexual cells in the Protozoa which is essentially of the same character as in the Metazoa (see Wilson, :00, pp. 227, 277, and Calkins, :01, p. 233). It is very interesting and remarkable that reduction phenomena should show the same order of events in animals and plants and the facts should be clearly recognized. But I cannot follow those botanists who carry over to the animal kingdom the phylogenetic conclusions which are so clear in plants. The remarkable agreement of the events of sporogenesis in plants with gametogenesis in animals appears to me likely to prove only another illustration of similar biological phenomena which have evolved independently of one another, an illustration comparable with the independent origin of sex, of heterospory, and probably even of the sporophyte generation itself (involving the processes of sporogenesis) in various groups of the plant kingdom.

We have considered this comparison of reduction phenomena in plants with animals chiefly to emphasize the clear cut morphology of the process as understood by the botanist. It does not matter how close the events of sporogenesis may come to those of gametogenesis in the higher angiosperms, the whole background of plant phylogeny, which is wonderfully clear as a whole, shows that reduction phenomena are the product of the asexual generation. It represents, as Strasburger has so well

expressed it ('94a, p. 288), a return on the part of the plant organism in each life history to the condition of an ancestral sexual generation (gametophyte). Reduction phenomena in themselves are not the result of a gradual evolution, whatever may be the complicated history of the sporophyte generation, for they consist always in the sudden reappearance of the primitive number of chromosomes, characteristic of the generation in which sex arose (gametophyte). The cause of reduction phenomena is phylogenetic. The interval that may separate this phenomenon from the responsible sexual act varies immensely in the plant kingdom according to the evolution of the groups concerned. But the suddenness of the appearance of sporogenesis tells in every case the same story of an immediate and total change in the potentialities of the protoplasm in the spore mother-cell, a change which can only be understood as a phylogenetic process deeply seated in the race.

When the events of sporogenesis in plants are considered as processes of spermatogenesis or oögenesis we disregard the most remarkable historic outlines that plant phylogeny can present, to the confusion of clear thought. Botanical science may well be proud of its achievement in outlining with such exactness the relations that the critical periods of gametogenesis, fertilization, and sporogenesis bear to reduction phenomena and too great stress can hardly be laid upon the importance of the results.

4. Reduction of the Chromosomes.

There are perhaps no activities of the cell which have been the subject of more investigation and discussion than those of chromosome reduction in animals and plants. The reasons are clear. The events of gametogenesis in animals and of sporogenesis in plants have the deepest significance for an understanding of the organization of protoplasm because these are periods when great changes are made evident in the structure of the cells concerned and at the same time in their potentialities. We are forced to conclude that some of the structural changes at least are the cause of the new potentialities and the attempt to establish the cause and effect has been one of the most fruitful and

interesting subjects of cell research. Reduction phenomena also have a deep phylogenetic significance whose history in plants at least can be traced with a remarkable degree of exactness.

We are confident that sporogenesis in plants signifies the sudden return of the organism to the condition of an ancestral sexual generation with the reappearance of a primitive number of chromosomes. The short time consumed in the process and the details and precision of the cell activities show that we are dealing with phenomena whose complicated mechanism can only find explanation in a long phylogenetic history. In the study of reduction phenomena and fertilization we have reached the conclusion that the chromosomes are intimately concerned with the transfer of hereditary qualities and are probably the chief or even the sole bearers of these characters. And thus we enter upon some of the most far reaching problems of biology, those of heredity, hybridization, and the basis for the remarkable ratios of inherited characters which Mendel first clearly set forth.

It seems quite certain for both animals and plants that numerical reduction of the chromosomes takes place through an association of the paternal and maternal chromosomes in pairs to form the reduced number of bivalent chromosomes (dyads). We have presented in Section IV ("Sexual Cell Unions and Nuclear Fusions") the evidence which indicates that paternal and maternal chromosomes do not unite at the immediate time of nuclear fusion in fertilization. On the contrary, in all higher animals and plants the paternal and maternal chromosomes are believed to remain separate throughout the long series of cell divisions in the new generation up to the time of sporogenesis in plants and gametogenesis in animals, both events being characterized by reduction phenomena. The fusion of the chromosomes takes place in the growth period which differentiates the spore mother-cell in plants from the archesporium or the primary gametocyte in animals from the preceding gametogenous tissue. The growth period is one of general protoplasmic accumulation and increase in the chromatin content of the nucleus, and is especially characterized by that peculiar activity in the nucleus termed synapsis. Evidence is accumulating that synapsis is the characteristic

feature of that period when the number of chromosomes is reduced by half.

Synapsis is followed very shortly by the two mitoses characteristic of sporogenesis. These nuclear divisions have given rise to a lengthy literature in which well known investigators have shifted their positions more than once. The discussions have centered on the methods of fission and distribution of the reduced number of bivalent chromosomes which appear in the first mitosis following synapsis. Assuming that the chromatin is organized into smaller units, represented by the chromatin granules (chromomeres, Fol, 1891), which compose the chromosomes, it is at once apparent that these finer elements may become variously distributed according to the structure of the bivalent chromosomes and the character of the mitoses of sporogenesis. Each fusion bivalent chromosome is composed of two chromosomes joined (1) end to end or (2) side by side or (3) it is possible that the chromatin is intricately mixed in the structure. With respect to the mitoses a transverse division of the fusion chromosomes might be expected to give a very different proportionate arrangement of the maternal and paternal chromatin from longitudinal divisions. Should the chromatin granules differ qualitatively from one another then different parts of a chromosome might be expected to have different characteristics which would be distributed by the mitoses of sporogenesis in various proportions or ratios.

It has long been known that the mitoses of sporogenesis present peculiarities in the mode of division and arrangement of the chromosomes at the nuclear plate which make them unlike the typical mitoses of cell division. These peculiarities have led to the designation of the first mitosis as heterotypic and the second as homotypic, terms which are now applied by both botanists and zoölogists although we have now a much more extended knowledge of each type than when Flemming first proposed the classification in 1887. We described the characters of the heterotypic and homotypic mitoses in Section III, "The Spore Mother-cell" (*Amer. Nat.*, vol. 38, p. 740, Oct., 1904), and will presently treat them further since some papers of the past year have opened again a discussion which seemed

closed a few months ago. The chief points of issue in discussions of reduction phenomena have centered around the significance of the heterotypic and homotypic mitoses. A typical mitosis is believed to present merely a quantitative division of each chromosome into two halves equivalent in their potentialities. The evidence for this view lies in the longitudinal fission by which each chromatin granule on the spirem is supposed to divide and contribute half of its substance to each daughter chromosome. Can there be a qualitative division of a chromosome by which one of the parts differs in character from the other, and are there such divisions at the time of sporogenesis in plants and gametogenesis in animals when reduction phenomena take place? These have been the chief topics of dispute in studies of this character for two decades.

The problem then ultimately concerns the structure of the chromosome and the reason for the constant reappearance of the number characteristic of the species at the beginning of each new gametophyte generation. All the prominent theories of heredity assume that the chromosomes are made up of simpler elements which stand for characteristics of the race. These may form various combinations of higher orders and collectively give the qualities of germ plasm. The simplest members that can be observed in such a series of structures are the chromatin granules (chromomeres) which may be found at almost all times in the nucleus and are especially conspicuous when arranged in a row on the linin thread of the spirem. Weismann has developed the most complex conception founded on the above principles and with the most elaborate terminology. Starting with the chromatin granule, which he named an id, Weismann assumed that this element is composed of still smaller structures called determinants and biophores, the last being the ultimate living units. Groups of ids make up idants or chromosomes. The id was conceived to possess all the essential characters of the specific germ plasm concerned but ids vary somewhat among themselves, determining thus the individual variations of the species. Therefore a chromosome or idant will have a varying structure according to the character and distribution of the ids which compose it.

When a chromosome divides longitudinally so that each id splits in half, the daughter chromosomes are exactly equivalent and the division of the chromatin is merely quantitative. But should a chromosome divide transversely then two sets of entire ids would be separated from one another and the two daughter chromosomes would differ in proportion as their component ids varied, *i. e.*, the division of the chromatin would be qualitative. These conceptions of the possible structure and mode of division of chromosomes outline the basis of Weismann's theory of heredity and will serve to illustrate the general attitude of those biologists who approach the subject from the standpoint of preformation, although none have cared to formulate such elaborate assumptions as Weismann. However, there is a general agreement among biologists of this school that elements are present in the chromatin which do carry hereditary characters and that the chromatin granule and chromosome have a definite architecture and organic value because of these elements.

Weismann's theory of heredity rests on an interpretation of the complexities of mitosis presented by Roux in 1883. Roux assumed that chromatin was not homogeneous in structure throughout the nucleus, but differed qualitatively in various regions. The elaborate history of mitosis with the formation and division of the chromosomes and their distribution through the mechanism of the spindle seemed inexplicable to Roux except on the theory that portions of the chromatin represented specific characteristics which were sorted and distributed accurately according to some system. There could be no need of such a complicated mechanism as mitosis if the distribution of the chromatin was to be merely quantitative for simple direct nuclear division could perform that operation as effectively as mitosis. Mitosis then became a device for the qualitative distribution of chromatin as well as quantitative and the characters of the daughter cells were determined chiefly by the specific elements which were given to one or the other.

Weismann siezed upon Roux's suggestion of a possible qualitative distribution of chromatin in mitosis and this assumption became a very important feature of his theory of heredity. Weismann postulated two methods of mitosis. By the first the

chromosomes are assumed to split longitudinally into equivalent halves, which are the facts in all vegetative or somatic mitoses so far as is known, and the chromatin is distributed quantitatively. By the second method chromosomes were conceived to split transversely so that one half is carried to each daughter nucleus, and if the two ends of a chromosome differed in the character of their fundamental elements (ids and determinants) the chromatin would be distributed qualitatively. Weismann prophesied in 1887 that this second type of nuclear division (qualitative mitosis) would be found and ever since investigators have steadily searched for a transverse division of the chromosomes. They have been reported in connection with the mitoses of chromosome reduction both for animals and plants and the history of these investigations forms an important part of the subject of reduction phenomena. But the present interpretation of these transverse divisions involves the consideration of factors that were unknown to Weismann and are very different from the significance assigned by him. The effect of Weismann's speculations, as a stimulus to investigations in these lines can, however, hardly be overestimated.

Botanical literature dealing with the two mitoses of sporogenesis presents a confusion of statements respecting the presence or absence of a transverse division of the chromosomes. Strasburger has changed his opinion three times. In his early studies Strasburger ('95) believed that the chromosomes divided longitudinally in both mitoses of sporogenesis. Then, led by studies of Mottier ('97) he concluded ('97b) that the fission of the chromosomes in the second mitosis was transverse. Almost immediately, however, Strasburger and Mottier reverted to the former opinion that the chromosomes divided longitudinally, a view which Strasburger maintained in his lengthy considerations of reduction phenomena in 1900a. Finally in a recent paper (:04b) Strasburger gives a very different interpretation of the events of the first mitosis (heterotypic), based on the study of Galtonia, and in general agreement with the most recent conclusions of Farmer and Moore (:03). Farmer ('95b), Farmer and Moore ('95), Miss Sargant ('96, '97), Guignard ('99a), Grégoire ('99), Lloyd (:02), and Mottier have also held that the divisions

of the chromosomes in the mitoses of sporogenesis were longitudinal with somewhat varying views, however, as to the exact time when the two divisions take place. On the other hand Ishikawa ('97), Calkins ('97), Belajeff ('98), and Atkinson ('99, for Trillium) have claimed that the second mitosis presented a transverse division. Dixon ('95, '96, :00) and Schaffner ('97) held a position apart from all these investigators, believing, that the chromosomes of the first mitosis of Lilium resulted from loops whose free ends became appressed or twisted together finally separating at the angle of the loop and thus constituting a transverse division in this first mitosis. These latter observations accord with the latest conclusions of Farmer and Moore (:03) and Strasburger (:04b). Most of this literature is reviewed in detail in Strasburger's paper of 1900a. We shall omit an historical discussion of this early work for the entire subject is approached from quite a different standpoint in the series of papers which have appeared in the past three years (1903–05) and which give hope of much clearer information on the mitoses of the spore mother-cell.

The remainder of this treatment of "Reduction of the Chromosomes" will take up the recent papers and try to show the drift of the present investigations. These papers had not appeared when the author described the behavior of chromosomes during mitosis in Section II (*Amer. Nat.*, vol. 38, p. 445, June, 1904) and presented the account of the spore mother-cell in Section III (*Amer. Nat.*, vol. 38, pp. 726, 740, Oct., 1904). At that time it seemed probable that Strasburger's conclusions of 1900 held true for all plants, namely, that the chromosomes split longitudinally in both mitoses of sporogenesis as well as in all other mitoses of the life history. Whether these views may have to be materially changed in the light of the most recent work is now a matter of dispute. Yet the ground has shifted so frequently in these perplexing problems that it is hard to feel sanguine of final conclusions even in the hopeful situation of the present. I shall take up the events of sporogenesis in order, beginning with the growth period and synapsis and ending with the two mitoses of the spore mother-cell.

The growth period always extends over a considerable length

of time and may occupy even weeks or months. During this interval the spore mother-cells increase to many times the size of the archesporial cells from which they were derived. There is an immense accumulation of protoplasmic material and a corresponding increase in the size of the nucleus and its chromatin content. The growth may be continued in the spores after the mitoses of sporogenesis, as is characteristically illustrated in the great increase in the size of the megaspores in the pteridophytes and certain embryo-sacs. The most striking nuclear activity of the growth period preceding the mitoses is synapsis. This term is applied to a very characteristic gathering of the chromatin and linin material in a compact tangle or ball at one side of the nucleus and usually near the nucleolus. Nuclei are sometimes in a state of synapsis for several days or perhaps weeks as is shown by the frequency of the stage in sporogenesis. Thus during the entire period of sporogenesis in Anthoceros from the inception of the spore mother-cell to the final differentiation of the spores (which must take many days) the period of synapsis occupies from one eighth to one sixth of the entire time (Davis, '99, p. 104). Synapsis has proved to be a very difficult subject for study and few investigators have made detailed observations upon its events. Some have claimed that synapsis is an artifact due either to poor fixation or to a particularly sensitive condition of the cell nucleus by which the chromatin was especially susceptible to shrinkage but it seems certain now that the phenomenon is entirely normal. Miss Sargant ('97, p. 195) has observed synapsis in the living pollen mother-cell of *Lilium martagon*. Anthoceros presents a particularly favorable subject for the study of the effects of fixing fluids on spore mother-cells because one may present all stages in the same sporophyte to identical conditions. In a series of experiments on this form (Davis, '99, p. 97) with a number of standard fixing fluids I have always found synapsis at exactly the same period in sporogenesis and at no other time in the process. True synapsis, characteristic of reduction phenomena must be carefully distinguished from other somewhat contracted conditions of the chromatin which are occasionally found in cells. Thus Miyake (*Annals of Bot.*, vol. 17, p. 358, 1903) noted the resemblance to synapsis

of an accumulation of granular material in the nucleus of the central cell of Picea and other cases might be cited which superficially resemble synapsis but have no fundamental relation to this peculiar nuclear activity.

Evidence is steadily accumulating that synapsis is a very important period of sporogenesis. Some authors hold, as will be described presently, that it is the time when paternal and maternal chromosomes, which have remained separate throughout the sporophyte generation, become associated in pairs to give the reduced number of the gametophyte. This conclusion makes synapsis the actual period of chromosome reduction and the two succeeding mitoses become merely distributing divisions of the newly formed chromosomes. Montgomery (:01) first suggested for animals that synapsis involved a union of maternal and paternal chromosomes in pairs. Other views, however, regard the reduction of the chromosomes as merely the temporary union of paternal and maternal elements, end to end, to form a bivalent chromosome characteristic of the first or heterotypic mitosis. According to this view the bivalent chromosomes divide transversely so that the halves are distributed as whole chromosomes in the first mitosis.

Two very important papers on reduction phenomena have appeared this year (1905) both of which were preceded by preliminary publications, that of Farmer and Moore (:03) and Allen (:04). These two accounts best represent the attitude of the opposing schools and will be made the chief texts of our treatment. The fundamental points of difference concern the events of synapsis and the heterotypic mitosis while there is complete agreement in the general interpretation of the homotypic mitosis. All authors have reached essentially the same conclusions as regards the purpose and final results of the reduction divisions but the details of the processes of synapsis and the prophase of the heterotypic mitosis are described in radically different ways by various investigators. However, as has been stated, the views fall into two groups or schools, one led by Farmer and Moore with whom Strasburger's recent paper, "Ueber Reduktionsteilung" (:04) expresses essential agreement. The other school includes Allen, Rosenberg, and the

botanists of the Carnoy Institute, Grégoire and Berghs. To the writer the conclusions of the second school seem better founded and we shall present them first. Allen's last paper (:05) gives the most complete statement of their interpretations.

Allen's conclusions (:03, :05) are based on the study of the pollen mother-cell of *Lilium canadense* and his account of synapsis in this form is of great interest for the simplicity of his explanation of the events of this phenomenon and their significance. The nucleus of the young pollen mother-cell following the last mitosis in the archesporium and previous to synapsis contains a network of large irregular masses connected by fibers of varying thickness. The irregular masses, which probably contain both chromatin and linin, are derived from the chromosomes of the previous mitosis but these structures cannot be recognized in the resting nucleus. Nucleoli are present among the irregular masses or chromatin knots but are readily distinguished from them. As the nucleus grows larger the chromatin knots become more widely separated, but synapsis does not occur until it has reached its full size.

During synapsis the reticulum becomes transformed into a definite spirem. The fibers connecting the chromatin knots increase in length and become more uniform in thickness while the knots become less conspicuous as though their material were drawn out along the fibers. The fibers of the reticulum are now seen to arrange themselves in pairs and a general contraction of the network takes place which is the beginning of synapsis. Allen believes that this contraction is associated with the approximation of the fibers. The contracting network occupies at first the center of the nucleus but later moves to the periphery where the nucleoli may be found flattened against the membrane. There is now a continuous spirem in the nucleus, plainly composed of two slender threads lying side by side and probably with no free ends. These two threads often run closely parallel, sometimes loosely twisted about one another, sometimes in contact and apparently fused and sometimes rather widely separated. It is clear that the double nature of the thread is not due to a fission but that two independent threads are developed indepen-

dently out of the reticulum. The two threads gradually fuse so that in older stages of synapsis the nucleus appears to contain a single relatively thick spirem which is shorter and more loosely coiled than in the earlier stages. The minute structure of the threads of the spirem can be determined by careful staining. They consist of a series of chromatin granules (chromomeres) imbedded in the ground substance, linin. As the two threads fuse the chromomeres generally come together in pairs and unite to form a single row of large chromomeres which project from the side of the larger single (fusion) spirem.

The single (fusion) spirem on emerging from synapsis becomes uniformly distributed throughout the nucleus. There appear to be no free ends in the much convoluted and looped thread. Some of the loops become fastened to the periphery of the nucleus but there is no regularity in the number of loops and no relation to the number of chromatic segments that are formed later. While thus evenly distributed the single spirem undergoes a longitudinal fission which is preceded by the division of each chromomere. This is the first longitudinal fission of the spirem which is well known through the descriptions of Guignard, Grégoire, Strasburger, Mottier, and others. The fission is not simultaneous throughout the length of the spirem, for some portions remain undivided for some time when contiguous parts are plainly split. The result is a condition very similar to that presented just before the fusion of the two systems of threads during synapsis which produced the single (fusion) spirem. It seems probable that the threads which become separated are morphologically the same as those which fused during synapsis although the union at that period seems complete. The split spirem remains uniformly distributed throughout the nucleus exhibiting, however, a tendency to become somewhat massed in the center of the nuclear cavity leaving fewer loops attached to the nuclear membrane.

The split spirem now segments throughout its length into the reduced number of chromosomes (12) characteristic of the heterotypic mitosis. The segmentation is not simultaneous, but the first free ends appear near or at the periphery of the nucleus where the split spirem breaks apart at the loops. As segmen-

tation proceeds the number of loops becomes fewer and the free ends more numerous. Allen finds the breaking apart of the arms of the loops, whose heads are at the periphery of the nucleus, as described by Schaffner ('97) and Farmer and Moore (:05), but cannot accept the interpretation of these latter authors (to be described presently). Allen's studies show that the loops are the points of separation of adjacent split chromosomes and not a point where the spirem bends on itself to form a pair of chromosomes. The ends of the split chromosomes when properly stained are seen to be distinct even though they may be in contact or apparently fused. At the time of the segmentation of the split spirem the two threads are generally twisted about one another.

The split chromosomes now shorten and thicken, the number of twists is reduced and the pairs of elements take on the many forms characteristic of the heterotypic mitosis and described as I's, J's, X's, Y's, V's, and O's. These chromosomes of the heterotypic mitosis are of course pairs of chromosomes, *i. e.*, bivalent chromosomes or dyads. They are believed to represent morphologically the full number of sporophytic chromosomes (24) now associated in pairs forming the reduced number (12) of bivalent chromosomes. The two threads which fuse are believed to represent two spirems of maternal and paternal origin and the chromosomes in the pairs are derived from different parents.

Shortly after the segmentation of the spirem the sporophytic chromosomes of each bivalent element or dyad may show evidence of a second longitudinal fission, first recognized by Grégoire ('99), Guignard ('99), and Strasburger (:00) which is completed during the metaphase of the heterotypic mitosis. The evidence consists in the appearance of a double row of granules in each sporophytic chromosome, the result of the division of the chromomeres. However, these chromomeres soon become indistinguishable from the linin and the chromosomes appear homogeneous from now on.

While the spindle of the heterotypic mitosis is being organized the position of the sporophytic chromosomes shifts with the development of the spindle fibers until they are brought to the

nuclear plate still grouped in pairs as dyads (bivalent chromosomes). The details of spindle formation and the heterotypic mitosis do not concern the present discussion of reduction phenomena. The reduction has occurred with the formation of the dyads and the mitosis simply distributes the 24 chromosomes (generally called daughter chromosomes) which are believed to be the morphological equivalents of the sporophytic chromosomes that entered the spore mother-cell from the archesporium.

Just before the separation of the sporophytic chromosomes during metaphase of the heterotypic mitosis a longitudinal fission appears suddenly in each element extending almost the whole length. This is the second longitudinal fission as interpreted by Grégoire ('99), Guignard ('99), Strasburger (:00), Mottier (:03), and others, with whom Allen is in full agreement. It is of course a premature division of the chromosomes preliminary to the homotypic mitosis. The second fission is probably completed at this time but the elements of each pair (formerly called granddaughter chromosomes) remain clinging together at one end by a peculiar overlapping of the hooked tips forming thus a V-shaped pair whose apex is drawn to the poles of the heterotypic spindle. The daughter nuclei following the heterotypic mitosis are not in a true resting condition and the chromosomes while forming a spirem show abundant evidence of independent structure. They emerge from the spirem at the prophase of the homotypic mitosis as the same morphological entities (*i. e.*, as V-shaped pairs) and are thus brought to the nuclear plate from which they are distributed generally as fairly straight rods to form the nuclei of the pollen grains.

Rosenberg's (:03a, :04a, :04b) studies on the hybrids of Drosera furnish further evidence that the chromosomes from different parents fuse in pairs during the prophase of the heterotypic mitosis. The gametophyte number of chromosomes in *Drosera rotundifolia* is ten and in *D. longifolia* twenty and those of the former species are larger than those of the latter. The sporophyte number in the hybrid is thirty as would be expected. At the heterotypic mitosis of sporogenesis, however, twenty chromosomes appear in the hybrid, half of which are plainly double structures and consist each of a larger and a

smaller element. During this mitosis the ten double chromosomes divide but the single chromosomes remain entire and either pass to one pole or the other or are left out in the formation of the daughter nuclei. The explanation of these conditions must be that ten chromosomes of *D. rotundifolia* fuse with ten from *D. longifolia* leaving ten of the latter without mates. Rosenberg's last paper (:04b) on Drosera describes in considerable detail the union of chromosomes in pairs in both species of Drosera during sporogenesis. The sporophytic chromosomes which at first are scattered throughout the nucleus in the early prophase of the first mitosis come together in pairs and unite so closely that there is hardly a trace of their dual nature in the resultant larger bivalent chromosomes, which are of course the gametophyte number. Rosenberg is very positive that the pairs of chromosomes are preliminary to a fusion and not the result of a fission of already reduced segments of a spirem thread. Rosenberg believes that the two halves of the bivalent chromosomes are separated in the first (heterotypic) mitosis and that each splits lengthwise prematurely during the first mitosis in preparation for the second. The fused bivalent chromosomes then appear to divide twice longitudinally but the first division may be only a separation of the two sporophytic chromosomes that entered into the fused pair.

We shall consider now the conclusions of Berghs and Grégoire of the Carnoy Institute, Louvain, whose publications have appeared practically simultaneously with some of those which we have just discussed. Berghs has published three papers (:04a, :04b, :05) treating of the early history of sporogenesis in Allium, Lilium, and Convallaria, and concludes from a study of synapsis that the spirem immediately preceding the heterotypic mitosis arises from the close association, side by side, of two delicate threads. These threads are organized previous to and during synapsis and their coming together brings about that contraction of the chromatic material characteristic of synapsis. The threads contain sporophytic chromosomes of the last mitosis in the archesporium. The apparent longitudinal fission of the spirem which precedes the heterotypic mitosis in the spore mother-cell is interpreted as being these two threads

which are believed to have never actually fused during synapsis. The reduced number of segments derived from the spirem preceding the heterotypic mitosis are then bivalent chromosomes composed of pairs of sporophytic chromosomes lying side by side. The heterotypic mitosis distributes the sporophytic chromosomes in two sets resulting in a numerical reduction of their numbers by one half. It will at once be noted that while Berghs and Allen have independently arrived at similar conclusions respecting the structure of the chromosomes of the heterotypic mitosis there are some important differences in the mode of origin. Allen reports an actual fusion of the two threads (paternal and maternal) during synapsis and a later fission of the spirem previous to the heterotypic mitosis. But the accounts of both authors have much in common in their interpretation of the structure of the spirem and chromosomes of the heterotypic mitosis which is fundamentally different from the accounts of Farmer and Moore, and Strasburger to be described later.

Grégoire (:04) in a general discussion of reduction phenomena confirms the observations of Berghs and takes a very positive position against the interpretations of Farmer and Moore and Strasburger. The chief features of his conclusions are in harmony with the results of Allen. The sporophytic (somatic) chromosomes are believed to become associated in pairs by the application of two delicate threads throughout their length during synapsis. These threads are believed to retain their autonomy and never actually to fuse although they may come in close contact. Consequently the reduced number of chromosomes are pairs of sporophytic chromosomes which have retained complete independence. Allen, on the contrary, reports a complete union of the two threads involving the fusion of chromomeres in pairs and a later longitudinal division throughout its length of the single (fusion) spirem. Grégoire does not regard the heterotypic mitosis as a true nuclear division but as a special process designed to effect this numerical separation of the sporophytic chromosomes and intercalated between typical mitoses, while Allen would apparently treat it as a true mitosis and regard the chromosome reduction as effected by the fusion of two sporophytic spirems during synapsis.

Rosenberg (: 05) has recently published a general review of reduction phenomena based on studies upon Listera, Tanecetum, Drosera, and Arum, taking a position in essential agreement with Allen and the investigators of the Carnoy Institute and in opposition to the theory of Farmer and Moore and Strasburger. Rosenberg does not quote Allen's preliminary paper (: 04) which anticipates his conclusions. He finds that the spirem which emerges from synapsis is preceded by a condition when the structure is clearly made up of two threads (spirems) which lie parallel to one another. These two threads are frequently joined together, and in places spirally twisted but here and there they may be seen to be entirely separated from one another. They finally form the single spirem which follows synapsis and which divides into the reduced number of chromatic segments. But the chromatic segments throughout the entire processes are shown to be double in structure (bivalent chromosomes), *i. e.*, composed of two chromosomes lying very close together side by side or even united. What appears to be a longitudinal fission of the chromatic segments of the spirem immediately preceding the first mitosis is really then a line of union along which the two independent threads have come together. The phenomenon of synapsis consists of this close association of two threads which are themselves simple spirems into a double spirem which segments into pairs of sporophytic chromosomes each of which may be regarded as a bivalent chromosome.

Farmer and Moore published a preliminary communication in 1903 which aroused much interest in their theory of chromosome reduction. The full account (: 05) has recently appeared. Their studies are upon Lilium, Osmunda, Psilotum, Aneura, and the cockroach, Periplaneta. Lilium and Osmunda among the plants were given chief attention and since the lily was the type studied by Allen it will serve best to contrast the conclusions of these two investigators. The accounts of Allen and Farmer are so fundamentally different as regards the events of synapsis and the prophase of the heterotypic mitosis that it seems scarcely possible that both can be right in their respective material, *Lilium candidum*, Farmer's type, and *L. canadense* of Allen's description. Farmer and Moore intro-

duce the terms "maiosis" and the "maiotic phase" to cover the whole series of nuclear changes included in the heterotypic and homotypic mitoses. The maiotic phase is regarded as similar in its essential details in both animals and plants but the fact of its appearance at different points in the life histories precludes any probability of relationship in such widely divergent lines. The events of synapsis and the consequent peculiarities of the heterotypic and homotypic mitoses are considered as intercalated between the series of typical mitoses in the life history.

Farmer and Moore's conclusions for *Lilium candidum* may be briefly summarized as follows. A definite spirem with the chromatin distributed as granules appears in the young spore mother-cell before its separation from neighboring elements. A "first contraction figure" now appears and the spirem thread becomes densely coiled in the vicinity of the nucleolus, this condition persisting for some time. Then the coils of the spirem loosen and become distributed about the periphery of the nuclear cavity, from the point of contraction as a center. A longitudinal fission of the spirem thread then appears, the chromatin granules dividing so that they come to lie in two parallel rows on the edge of the split ribbon. The fission is irregular and open loops appear at places. The spirem then shortens and the split gradually closes up and becomes very difficult to recognize. Many of the convolutions of the thread are attached to the nuclear membrane while the remainder form a tangle in the interior around the nucleolus which is believed to give up much of its substance to the chromatic portion of the spirem. Farmer and Moore then fail to find the double thread and its union during synapsis to form a single (fusion) spirem which is a fundamental feature of Allen's account.

There follows then a stage which has been the subject of much discussion. According to Farmer and Moore the spirem thread becomes pulled out into V- and U-shaped loops, shown with especial clearness where the bend of the loop is attached to the periphery of the nuclear membrane. The arms of the V's then come to lie parallel and so close together as to give the appearance of a fission in a structure which is really the result of an approximation of the two free ends of what was a loop.

The spirem thread thus breaks up into segments which, however, lie in pairs represented by the V's in the reduced (gametophyte) number. The pairs are bivalent chromosomes, each composed of two sporophytic chromosomes which were arranged serially on a single spirem thread. The pairs are not always organized through the approximation of the arms of V-shaped loops but this is a very characteristic type of structure. The V's have been interpreted by other authors as the approximation of portions of the spirem thread (Dixon, '95, '96, :00) or the separation of their free ends at the bend of the loop as a transverse division of a reduced number of looped chromosomes in the heterotypic mitosis (Schaffner, '97). The two parts of the bivalent chromosomes (which are pairs of somatic chromosomes) now become shorter and thicker and all trace of the original fission of the spirem thread is lost.

The essential features of Farmer and Moore's interpretation of the prophase of the heterotypic mitosis are, then: (1) a single spirem with the sporophytic chromosomes arranged serially, which splits only once longitudinally, the fission afterward becoming obliterated when the chromosomes are organized, and (2) the organization of bivalent chromosomes in the reduced number largely by the approximation of the free ends of loops which entails a separation at the bend of the loops of the two sporophytic chromosomes, giving the appearance of a transverse division.

The heterotypic mitosis, then, according to Farmer and Moore involves merely the distribution of the sporophytic chromosomes arranged in pairs (bivalent chromosomes) as univalent elements to each daughter nucleus. This is of course the general conclusion of all recent investigators, the different views being the result of varying accounts of the method of organization of the bivalent chromosomes. During this distribution in the heterotypic mitosis the split of the original spirem appears in each univalent element (sporophytic chromosome) and the halves open throughout the greater part of their length giving the peculiar V-shaped daughter chromosomes so characteristic of this mitosis in the lily. The arms of these V's become the daughter chromosomes of the homotypic mitosis which are thus

formed prematurely during the heterotypic as was first described by Grégoire ('99). However, Grégoire and most botanists have considered the split between the V's as a second longitudinal fission of the original spirem in the spore mother-cell while Farmer and Moore regard it as the reappearance of an original single fission. This view of Grégoire, which has had the support of Guignard ('99), Strasburger (:00), and Mottier (:03), is the theory of a double longitudinal splitting of the chromosomes previous to the heterotypic mitosis and is also maintained in Allen's (:05) recent paper.

The homotypic mitosis brings about the final separation of the arms of the V-shaped longitudinally split univalent (sporophytic) chromosomes of the heterotypic division. The fact that the arms of these V's finally break apart at the ends does not constitute a transverse division as has been claimed by some earlier writers (Ishikawa, '97; Calkins, '97; Belajeff, '98; Atkinson, '99, for Trillium). The peculiarities of the homotypic mitosis are then due to the premature fission of the univalent chromosomes during the heterotypic. As a type of nuclear division the homotypic mitosis is not fundamentally different from the typical divisions of other periods of the life history. All recent authors are in agreement on this interpretation of the events of the homotypic mitosis.

Gregory (:04) gives an account of sporogenesis for several leptosporangiate ferns and accepts Farmer and Moore's explanation of reduction phenomena. He finds the same sort of U-shaped segments in the reduced number at the heterotypic division and considers them bivalent chromosomes which divide transversely so that the original sporophyte chromosomes are distributed in two sets during this mitosis. The various positions assumed by the limbs of the U-shaped segments give appearances very similar to the tetrads described in the heterotypic mitosis of animals and which Calkins ('97) reported for Pteris and Adiantum and regarded as resulting from the transverse division of the halves of a longitudinally split chromosome. Gregory of course cannot accept the conclusions of Calkins.

Williams (:04a) applies the theory of Farmer and Moore respecting the bivalent character of the chromosomes in the

heterotypic mitosis to his studies on the first division in the tetraspore mother-cell of Dictyota. But it can hardly be said that his account offers any material support to the theory. There is a clear synapsis stage preceding the mitosis in this form from which a spirem emerges as a beaded thread. This spirem then becomes split longitudinally and later the chromosomes are organized and show a longitudinal fission. The form of the chromosomes at metaphase of the first mitosis is heterotypic, a ring form being prevalent, and Williams concludes that it is developed by the bending and closing of the free ends of a loop. The events of synapsis are not clearly enough known to make possible a comparison with the accounts of Allen and Berghs.

We are now ready to take up the latest conclusions of Strasburger (: 04b) which are closely associated with views expressed in a recent paper of Lotsy (: 04). Lotsy gives a clear statement, illustrated with many diagrams of the various ways in which sporophytic chromosomes may be conceived to unite in pairs previous to the first mitosis in the spore mother-cell and the manner in which the resultant bivalent chromosomes may be divided and distributed by the two mitoses of sporogenesis. Lotsy makes parallel comparisons between sporogenesis in plants and gametogenesis in animals and proposes the term "Gonotokonten" ("Nachkommenbildner") for the mother-cells which inaugurate reduction phenomena. The paper presents no new observations but discusses the problems of reduction in their broad aspects. An excellent summary is given by Kœnicke (: 04).

Strasburger's (: 04b) most recent paper, "Ueber Reduktionsteilung," is based chiefly on studies of Galtonia and Tradescantia and presents an entire change of view from his conclusions of 1900. Galtonia seems to be a very favorable form for study since the gametophyte number of chromosomes is only six and the structures are exceptionally clearly differentiated in the spore mother-cells, which Strasburger calls "Gonotokonten" after Lotsy. A single spirem is reported to split longitudinally but the two daughter threads remain close together. The spirem then shortens and thickens and becomes distributed in heavy

loops. It finally divides into six segments which are interpreted to be six pairs of chromosomes joined end to end. These six segments are then bivalent chromosomes. The two chromosomes of each pair (segment) finally come to lie side by side in various positions by the bending of the original looped segments and the separation of their two ends in the middle. The halves of the six bivalent chromosomes (segments) are distributed by the first mitosis so that there is the effect of a transverse division of six chromosomes at this time, but really the process is one of the distribution of twelve chromosomes in two sets of six each. The longitudinal fission of the spirem thread becomes more conspicuous towards the end of the first mitosis so that the twelve chromosomes become partially split and pass as V's to the poles of the first spindle during telophase. This premature division is preparatory for the second mitosis (homotypic) when the separation is finally effected. There is then only one longitudinal fission of the original spirem in the spore mother-cell and this prepares the chromosomes for the second mitosis, which differs only from the typical mitoses in the premature splitting of its chromosomes. The first mitosis is merely the separation of pairs of chromosomes joined end to end. Strasburger interprets the conditions in Tradescantia and Lilium in a similar way believing that the complications there simply arise from a more involved looping of the spirem thread. Strasburger's account of Galtonia then supports in all essentials the theory of Farmer and Moore.

Strasburger in the same paper (:04b) gives an account of synapsis which cannot be brought into harmony with that of Allen. The chromatin granules are reported to gather during synapsis into as many centers, which he names "Gamozentren," as will finally form the reduced number of bivalent chromosomes (six in Galtonia). The "Gamozentren" then become arranged and drawn out into the spirem which emerges from synapsis. The chromatin granules are named "Gamosomen" and the bodies formed in the "Gamozentren" which afterwards become the bivalent chromosomes of the first mitosis are called "Zygosomen." There are then no organized chromosomes during synapsis and no place in Strasburger's account for the fusion of

a fully organized paternal and maternal spirem as described by Allen. The identity of the sporophytic chromosomes becomes entirely lost, according to Strasburger's explanation of synapsis, and the chromatin granules ("Gamosomen") may be variously distributed in the new set of bivalent chromosomes ("Zygosomen"). These "Zygosomen" are a new creation in the cell. All of the other theories, on the other hand, preserve the morphological entity of the sporophyte chromosomes which are of course of maternal and paternal origin but allows their distribution in various ratios to one another during the first mitosis of sporogenesis. The chromosome, however, remains a fixed morphological structure from one generation to another. These are fundamental differences which have a vital bearing on the discussion of hybridization, which will follow shortly, since one of the most important features of the problems concerns the preservation of the relative purity of the germ plasm.

The chief characteristics of the two theories of reduction may be summarized as follows: —

(1) According to Allen, Rosenberg, Berghs, and Grégoire, the phenomenon of synapsis presents a close association of two parallel chromatic threads (probably of maternal and paternal origin) which finally unite to form the spirem that precedes the heterotypic mitosis. This single (fusion) spirem is then double in nature and the longitudinal fission which follows, is the separation of the two threads that entered into its composition. The reduced number of chromatic segments of the heterotypic mitosis are bivalent chromosomes or more precisely pairs of sporophytic chromosomes derived from the two (maternal and paternal) threads of the synapsis stage. The heterotypic mitosis distributes the sporophytic chromosomes in two sets thus effecting a numerical reduction by one half. The sporophytic chromosomes divide prematurely during the heterotypic mitosis in preparation for the homotypic thus presenting a second longitudinal fission of the segments derived from the single (fusion) spirem. A special feature of Allen's studies is the fusion of chromomeres in pairs during the organization of the single (fusion) spirem and a subsequent splitting of each larger chromomere with the longitudinal fission of this structure.

(2) Farmer and Moore, Gregory, Williams, and Strasburger hold that there is primarily only a single chromatic thread in the nucleus of the spore mother-cell which is the spirem of synapsis and the heterotypic mitosis and which most of these authors believe to be composed of the full number of chromosomes (sporophytic) joined end to end. This spirem splits longitudinally but the fission is a premature division which prepares the chromosomes for the homotypic mitosis. The chromosomes of the heterotypic mitosis are formed from loops of the spirem which include a pair of sporophytic chromosomes joined end to end. The members of this pair come to lie side by side by an approximation of the arms of the loops and a breaking apart at the head of the structure. This transverse fission of the spirem is not of course a transverse division of a chromosome but merely the separation of a pair of chromosomes joined end to end. The line between the two arms of the loop marks a region of contact due to approximation and not a line of fission. The heterotypic mitosis effects a numerical reduction of the chromosomes as in the first view but these chromosomes are formed on entirely different principles. A single premature fission of the spirem or its segments prepares the chromosomes for the homotypic mitosis.

Comparing the two schools, it may be noted that they both explain reduction phenomena as a numerical reduction of the double set of sporophytic chromosomes by a distribution in two sets. The fission of the chromosomes is always quantitative and there is no hint in any of the views of a qualitative division in Weismann's sense. Furthermore, most of the investigators are firmly convinced of the individuality of the chromosomes which means that they are convinced as morphological entities persisting from one generation to the next. This is an important agreement in relation to theories of heredity and hybridization which we shall discuss at another time (see treatment of "Hybridization"). The differences lie in questions of fact regarding the organization of these chromosomes in the spore mother-cell and their behavior during synapsis and at other periods of prophase in the heterotypic mitosis. There is entire accord in that the chromosomes of the homotypic mitosis appear

during the metaphase of the heterotypic but a fundamental difference in the accounts of the manner in which these structures are formed.

In conclusion, we may very briefly note the fact that the zoölogists are divided into two schools in their accounts of reduction phenomena, apparently along similar lines to those of the botanists. Some recent papers (Winiwarter, :00; Schoenfeld, :01; and the Schreiners, :04) have described the union of parallel threads (maternal and paternal) during synapsis to form a single spirem in the rabbit, man, bull, hag-fish, and shark. Winiwarter and the Schreiners regard a later longitudinal fission of the spirem as a separation of the two threads which originally entered into the structure. The chromosomes in the hag-fish (Myxine, the Schreiners, :04) are organized in pairs side by side and a second longitudinal split appears in each. The heterotypic mitosis separates the groups in the plane of the first fission and the two parted chromosomes are divided by the homotypic. This history is essentially similar to Allen's account of the lily. On the other hand there is a large body of observations founded on the investigations of Häcker, vom Rath, Rückert, Montgomery, and others, indicating that bivalent chromosomes are formed consisting of somatic chromosomes joined end to end and that these elements or their derivatives are distributed either with the heterotypic or homotypic mitosis. This of course involves a transverse division which is, however, interpreted as the separation of adjacent chromosomes and not as a qualitative division in Weismann's sense. The attitude of the first group is clearly similar to that of Allen, Rosenberg, Berghs, and Grégoire among the botanists, while that of the second shows many points of similarity to the theory of Farmer and Moore and to Strasburger's last view (:04). There are a number of accounts of a double longitudinal fission of chromosomes especially among the vertebrates, which have not been harmonized with the last view but may find explanation along the lines of the more recent investigations.

It is of course conceivable that there are two distinct types of arrangement of sporophytic and somatic chromosomes in animals and plants at synapsis during gametogenesis and sporogenesis.

It is possible that they may be grouped in pairs (bivalent chromosomes) either side by side through two parallel threads (paternal and maternal spirems) or end to end in a single chromatic thread. But it will certainly be interesting if animals and plants both show variations in these respects and very remarkable if the same genus, as Lilium, should present contrasting types of reduction phenomena. And on these points must be concentrated the future investigations in this field.

While we are making progress in our understanding of the behavior of the chromosomes it must never be forgotten that in them we are dealing only with the most conspicuous form of germ plasm and that there are much finer elements which in their turn will demand attention. We may hold to the view of the individuality of the chromosomes as morphological entities but nevertheless we must recognize the fact that the substance of these bodies which stand for parental characters, the idioplasm of Nägeli, may pass through remarkable changes which are far from understood. There is much evidence that the parental idioplasm may mix or combine during synapsis in the organization of the spirem from which are developed the reduced number of bivalent chromosomes. Allen has described the actual fusion of sets of chromomeres believed to be of maternal and paternal origin and there are many possibilities of the two idioplasms reacting upon one another to bring about intimate and fundamental interrelations. These become important principles in discussions of heredity and hybridization and will be considered later. Allen (:05, pp. 246–252) presents an admirable analysis of these problems.

NOTES AND LITERATURE.

ZOÖLOGY.

McMurrich's Human Embryology.[1] — In 1902, Dr. McMurrich published an excellent handbook of human embryology, well adapted to the needs of students of medicine, and it is a matter of gratification to others than the author that its sales have been such as to demand a second edition. In the preparation of the new edition, the author has revised the whole, changing the wording here and there, replacing some cuts and adding two others, while in parts the text has been re-written so as to incorporate the results of later investigations. Thus he has added Conklin's explanation of inversion of right and left sides; the account of the fate of the somatic layer of the myotome is changed, and with it in other parts modifications in the account of the derma, and in the idea of a segmentation in the skin. There is added an account of the chorionic vessels, and a statement as to the origin of the decidual cells; the account of the heart muscles has been changed, as has that of the histogenesis of striped muscle, and Minot's work on the sinusoids has been incorporated in the text.

There are very considerable changes in the account of the arteries of the trunk and umbilicus; the section on the metanephros has been re-written, the account of the lymph nodes has been changed, as has that of the relations of the corpus callosum and the fornix. There are also modifications in the statements regarding the endolymph ducts and the formation of the vitreous body. The most extensive and important changes, however, are in those parts which relate to the musculature of the limbs, where the author has revised the matter in the light of his own researches.

Dr. McMurrich has embraced the opportunity to add slightly (24 titles) to the bibliographies and to correct various typographical and other errors; but as Huxley wrote Foster (*Life*, vol. 2, p. 65), we

[1] McMurrich, J. Playfair. *The Development of the Human Body. A manual of human embryology.* Philadelphia, P. Blakiston's Son & Co., 1904. 2d ed., 8vo, pp. xix + 17–539, 272 text figs. $3.00.

wish he would "get rid of that terrible word 'urinogenital.'" On page 190 the suprasternal bones are spoken of as cartilaginous in origin, and are also regarded as representing the episternum of the lower vertebrates, but the episternum is membranous in origin. On page 202 there is a confusion in relation to the maxillary bones and "their cartilaginous representatives" in the lower vertebrates. The printing of the new edition is an improvement on the first, especially that of the cuts. We commend the work in the highest terms as a clear, accurate, and modern account of the development of man.

J. S. K.

The Arthropods and Cœlenterates of the Maldive and Laccadive Archipelagoes.[1] — In this part of this work are five articles dealing with certain groups of Arthropods and Cœlenterates and a notice of two parasitic worms. Professor S. J. Hickson treats of the Gorgonacea and certain other Alcyonarians. Thirteen species of Gorgoniids are enumerated, of which six are regarded as new, all coming from water of thirty fathoms or less in depth. A single species of Pennatula was found and a new species of Eunepthya is described. Mr. Borrodaile deals with the twenty-three species of hydroids collected, eight of them being new. Lictorella shows some interesting features, there being, besides the normal hydrotheca, others nearly four times as large, each with a hydranth at the bottom. These are regarded by Borrodaile as gonothecæ, although no gonophores were found, and on this account he would not agree with some authorities in uniting Lictorella with Lafœa, since in the former there would not be any Coppinia condition. Synthecium also presents some problems for solution. An interesting habitat is recorded for an unidentified species of Campanularia. It occurred attached to the body of a sea snake. Borrodaile recalls in this connection a similar association of a species of Stylactis with a fish but has overlooked Fewkes' *Hydrichthys mirus* which occurred on a teleost on the south coast of New England.

The hermit crabs are discussed by Major Alcock, who enumerates twenty-six species, of which four are new. The shrimps of the family Alpheidæ were especially numerous, and H. Coutière enumerates seventy-six species belonging to the group, a large proportion of these being regarded as new. Twenty species of Hemiptera are

[1] Gardiner, J. S., ed. *The Fauna and Geography of the Maldive and Laccadive Archipelagoes.* Cambridge Univ. Press, Engl., 1905. Vol. 2, pt. 4, pp. 807–921, pls. 67–87, text figs.

catalogued by W. L. Distant, all of which were previously known from British India. A. E. Shipley records a species each of Nematode and Trematode worms.

J. S. K.

Townsend's Birds of Essex County, Massachusetts.[1]— This book is all that its name implies and it is much more. Not only is it one of the most important recent contributions to faunal literature, but the extended notes on the habits of many birds make it a valuable treatise in ornithological bionomics. Of the three hundred and fifty-two large pages, the first seventy-three consist of nine chapters on topography and faunal areas; the birds of the ocean, the beaches, the dunes, the salt and the fresh marshes, and the ponds; lighthouse records; and the ornithological history of the County. It will be apparent that the stress is laid on the water birds in these introductory chapters, and this is only natural in view of the fact that Essex is a maritime county, and that Ipswich, with its beach, marshes, and dunes, is one of the most interesting localities ornithologically on the coast, besides being the summer home of the author. So, too, the biographical matter contained in the Annotated List which makes up the bulk of the volume is chiefly in connection with the birds of the sea and the shore, including, however, such passerine species as the Horned Lark, the Snow Bunting, the Lapland Longspur, and the Ipswich Sparrow. These notes on the habits of birds are almost entirely original, the results of Dr. Townsend's patient and penetrating observations covering many years of field work as collector and observer. The treatment of certain of the more interesting species is minute and well-nigh exhaustive,— though the author very properly confines himself to the habits as manifested in Essex County and has nothing to say, for instance, of the breeding habits of birds that do not breed in the County. Thus the account of the Herring Gull occupies seven and a half pages, in which, among other things, is advanced the theory that the large flocks of gulls found in summer on the Ipswich shore are made up of daily visitors from the Maine breeding-grounds. Dr. Townsend also treats the Black Duck very fully and presents interesting data as to the status of *Anas obscura rubripes*, the recently separated subspecies. Con-

[1] Townsend, Charles Wendell, M. D. *The Birds of Essex County, Massachusetts.* Memoirs of the Nuttall Ornithological Club, no. 3. 352 pp., frontispiece, map. 4to, published by the Club, Cambridge, Mass., 1905. $2.50.

siderable attention is also paid to the field identification of the several species. The distinguishing marks of our two cormorants, for instance, are pointed out, and other birds usually puzzling to the mere observer are shown to be identifiable in the field with the use of due care.

It would be unfair to convey the impression that the book is solely a record of personal experience or that the observations have been confined to Ipswich and its immediate neighborhood. As a matter of fact the author is well acquainted with the County as a whole, and he has made the fullest use of the observations of others, both published and unpublished, consulting the literature and examining collections. Nevertheless, the book remains to an unusual degree a personal achievement, upon which Dr. Townsend is to be heartily congratulated. The book is written in a direct, forcible style, with an abundant enthusiasm which is tempered by an eminently scientific attitude of mind and a discriminating sense of humor. It makes excellent reading even when read consecutively, and after perusal it should take its place on the ornithologist's shelves alongside of Major Bendire's *Life Histories.*

The volume is excellently printed on good paper and has a bibliography, a full index, a view of a typical sand dune with adjoining beach, and a map of the County.

F. H. A.

Notes.—The finer structure of the heart of the higher crustaceans has been worked out by Gadzikiewicz (*Jena. Zeitschr.*, Bd. 39, p. 203) with the following results. The heart proper consists of two layers: an inner muscular and an outer adventitia; no endocardium is present. The histological characteristics of these two layers are described in detail for many crustaceans.

A systematic account of the anatomy of Haliotis has just been published by H. J. Fleure (*Jena. Zeitschr.*, Bd. 39, p. 245). The author believes that Pleurotomaria and Haliotis are near relatives but are not derived one from the other. They are probably early derivatives from the common prosobranchian stem but not so early as the Docoglossæ and Fissurella.

The histology of the tunicate blood vessels has been investigated by Fernandez (*Jena. Zeitschr.*, Bd. 39, p. 325), who concludes that the blood system in these animals consists of two parts: the propelling part composed of the infolded pericardial wall or heart proper, and the transmitting part made up of the walls of the blood vessels and the inner connective-tissue layer of the heart.

CORRESPONDENCE.

A Biological Station in Greenland.

Editor of the American Naturalist.

Sir: — The great liberality shown in the United States in distributing money for educational purposes, both from the State and from wealthy people is, as is well known, not shared in other countries. It, therefore, still more becomes our duty to take interest in any cause which will further the study of biology in any part of the world where the biologist has to deal with financial difficulties.

Dr. Morten P. Porsild, a Danish botanist, has asked his government to erect a biological station in Greenland, and as science, in the truest sense of the word, is international it is of just as great interest to us in America, as it is to the Danish biologists that such a station should be erected. In order to show our interest in the proposed station I thought it worth while to consider, in a few words, the importance of such a station from a scientific point of view.

The importance of biological stations has been more and more emphasized as our views of biological problems have widened. We have just passed over a crisis in which the entire time of the zoölogist was spent in the laboratory, in microscopical study, and have passed into a wider field, have enlarged the meaning of the word biology. It does not mean the study of structure merely, but function, not merely morphology but physiology, and all the factors which influence it; not individuals only but groups and relations between groups; it means the science of life in all its branches and their mutual dependence on each other. The recent investigations of Professor J. Loeb have emphasized this fact. The whole field of experimental zoölogy emphasizes the importance of studying animal life and of studying it scientifically. Many of our greatest biological problems are to be solved by studying outdoor zoölogy. A great work is yet to be written on how and to what extent selection works in Nature. The question of variation is left to the student of the complex phenomenon of environment under which these animals live and develop and how these conditions effect a given species; it is not a question for the mere systematist but the student of animal life, of

microphysiology for the student of biology in the widest sense of the word. To study phylogenetic development from structures only is to study results without causes. The important study of *relations* is a study of animal life. The whole field of economic zoölogy asks for better knowledge of outdoor zoölogy. In a word, the recent path of zoölogical investigation has been to go back to the methods of our great master, Charles Darwin, and use as an aid our detailed microscopical study which has absorbed almost the entire time of the zoölogist for years.

If these are true interpretations we must hail every new opportunity given the student of zoölogy in any part of the world to study animals in their natural surroundings, and on a scientific basis. Especially is such the case when we are hoping to get a biological station in Greenland where the conditions and fauna are so different from those of any place where similar stations are found. The student of variation will then have an opportunity of transferring animals from one extreme climate to another. A thorough knowledge of how the fauna is adapted to the surroundings in a land where the sun never sets for three months and never is seen for a still longer period of the year will surely yield some interesting results.

All the great groups of invertebrates, and vertebrates with the exception of the amphibians and reptiles, are represented in Greenland. The flora is surprisingly large so there is no lack of opportunities for study as soon as a well equipped laboratory is established there. According to the estimate of Mr. Porsild the trip from Copenhagen and return and one year's study in Greenland would, under those conditions, be reduced to one third of the present expense or to $375.

The economic importance of such a station I have had various opportunities to show, and I need not point them out here but enough to say that Denmark ought to learn from the United States to protect her industries of hunting and fishing, and this can only be done in Greenland by having competent people there to protect these industries.

It is to be hoped that the government of Denmark will do its share in furthering the study of biology by offering the small sum of a few thousand dollars for such a station which will be of great value both from a scientific and an economic point of view.

MARTIN E. HENRIKSEN.

OHIO STATE UNIVERSITY.

Fleas and Disease.

Editor of the American Naturalist.

Sir: — No less epoch-marking than the announcements first made of the connection of mosquitoes with malaria and yellow fever, is the news which now comes through Dr. Ashmead, the leprosy expert of New York, that Dr. Carrasquillo of Bogota has found the bacillus of Hansen in the intestinal canal of fleas. The rapid progress of leprosy after introduction into some of our flea-infested southern cities, from local endemicity to alarming epidemicity, is, according to Dr. Ashmead, probably to be credited to inoculation by flea bites.

In connection with the investigation of the relation of fleas to bubonic plague, it has already been shown by the writer (*Proc. U. S. Nat. Mus.*, vol. 27, 1904), that the fleas of rats in the warmer regions of the earth are close relatives of the flea specific to human beings, and thus, far more likely to bite human beings than are the fleas of rats in the colder regions, which are only distantly related to *Pulex irritans*. It is now necessary to know if any of these southern rat fleas — of which there are a number of species — voluntarily bite human beings.

These investigations, and now the new lines brought into striking prominence by Dr. Ashmead's announcement, make it of first importance that a complete study be made of all the species of fleas occurring on rats, mice, dogs, cats, and human beings throughout the United States and tropical America, since any well founded medical and bacteriological investigations of the subject must be based on a thorough scientific knowledge of the fleas themselves, just as in the case of the mosquitoes in their relation to yellow fever. The utmost gravity of the possibilities involved not only justifies but renders imperative a careful and complete survey. The writer has in progress such a work, in continuation of extensive papers on the fleas already published. Residence in the tropics and in a leprosy center, together with the hearty coöperation of Dr. Howard of Washington, Dr. Lutz of Sao Paulo, Brazil, Dr. Carter of the University of Texas at Galveston, and others, has made possible a good beginning. It is hard to see how anything like a complete survey could be made without also the active coöperation of college and medical men in every part of these regions, the Hawaiian Islands, and the tropical regions of the far east. The simplicity of the apparatus needed (tweezers,

small homœopathic vials of alcohol, and several rat traps) and the ease with which material can be gathered from rats, dogs, cats, and human beings, should make possible the ready coöperation of all biologists and medical men and a hearty invitation is herewith extended to all such and to any other persons interested. As large series of specimens as possible should be taken and full data as to locality, host, etc., should be inserted in every vial. A direct report will be immediately returned for all specimens sent either to the writer or to Dr. L. O. Howard, Government Entomologist, in Washington, U. S. A., and full published credit will later be given for every sending.

It will greatly facilitate the rapid progress of the work if entomological, zoölogical, medical, and pharmaceutical journals the world over will kindly copy this notice.

C. F. BAKER.

ESTACION AGRONOMICA,
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THE AMERICAN NATURALIST

A MONTHLY JOURNAL
DEVOTED TO THE NATURAL SCIENCES
IN THEIR WIDEST SENSE

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THE

AMERICAN NATURALIST.

Vol. XXXIX. *August, 1905.* No. 464.

A SYSTEMATIC STUDY OF THE SALICACEÆ.

D. P. PENHALLOW.

In attempting a discussion of the Salicaceæ from the standpoint of their ancestry, as presented in the woody structure of the mature stem, a first step involves comparison with previously existing forms and with closely related types now extant, in order to determine the general phylogenetic sequence and the position which the group at present occupies. We are therefore led, at the very outset, to ask: (1) what is the nature of the evidence to be derived from paleontology, and what is the bearing of such evidence; and (2) what is the nature and bearing of the evidence to be derived from the structure of existing species? The Salicaceæ as we now know them, are altogether confined to two genera — Populus and Salix — of very wide distribution in north temperate latitudes whence they extend beyond the extreme northern limit of tree growth within the polar circle, being there reduced to prostrate shrubs. It is quite possible that the family may have been more extensive in early or middle Mesozoic time, but the evidence now available as derived from their fossil remains, leads us to the supposition that it has not been, at any previous time in its history, of a more comprehensive character. In common with many other

families of Dicotyledons, it made its appearance very abruptly in the Cretaceous age, whence it has continued through succeeding formations, appearing with prominence in the Pleistocene where its remains form a distinctly connecting link with existing species, with many of which they are more or less identical.

An analysis of the Salicaceæ based upon the enumeration of the Index Kewensis, shows that there are at the present time no less than two hundred and seventy recognized species, an altogether unusual proportion for a family embracing such a limited number of genera. Of these, twenty-two belong to the genus Populus, while two hundred and forty-eight belong to the genus Salix.

The poplars are preëminently a type peculiar to the northern hemisphere, and in their chief aspects they have a strong tendency to a boreal habit, the one exception to be met with in the subtropical *P. mexicana* offering no material contradiction of this law. *P. ciliata* of the Himalayas, though reaching a latitude far below that of most representatives of the genus, nevertheless conforms to the temperate habit of the group by virtue of the somewhat high elevations at which it grows. Six species range from Japan through China, Mongolia, and Siberia to Central Asia, while the western extension of the genus is carried through northern and central Europe as far south as Spain and Italy. In the western hemisphere, no less than ten species are to be met with, ranging from Mexico as the extreme southern extension, thence northward as far as the arctic circle where *P. balsamifera* appears to establish the limit of development. The very remarkable isolation and localization of the various species is one of the most prominent features disclosed by an examination of these plants. *P. mexicana* is confined to Mexico and similarly *P. ciliata* is peculiar to the Himalayas. *P. adenopoda* is restricted to China as *P. sieboldii* is to Japan; while *P. przewalskii* of Mongolia and *P. pruinosa* of Siberia, as also *P. euphratica* of Central Asia, give emphasis to this strong segregation, since they are as wholly distinct from the European and American species as are those of the last two regions from one another. In only one instance does there seem to be any

connecting form. This is presented in the ubiquitous balsam poplar of Asia and North America which not only serves to connect the types of both hemispheres, but it gives to the genus a greater range of latitude than any other species. Evidence of this nature would naturally lead to the supposition that *P. balsamifera* may represent a more generalized type ancestral to many of the associated species. But on the other hand, the very extensive distribution of distinct species occupying essentially isolated and often very widely separated regions, suggests a more general dispersal during Cretaceous and Tertiary time, and their eventual restriction to more limited areas through the operation of important physical agencies, with the survival of the more resistent but not necessarily the oldest species. In particular it is conceivable that such restriction may have been brought about in one of two ways: (1) the elimination of the ancestral type or types, of which *P. balsamifera* may possibly be regarded as the sole survivor, would tend to leave the descendants isolated as now found; (2) the ancestral forms having disappeared at a comparatively early period in the history of the genus, more recent physical changes in the earth's crust and in climatic conditions would give rise to more or less profound alterations in distribution in such a way as to effect a more pronounced segregation and localization. That such causes have been operative in glacial times is well known, and they have left a very definite impress upon the distribution of the existing flora of this continent, as particularly indicated by the various forms of alpine vegetation (Gray, '89, vol. 1, p. 122; vol. 2, pp. 24, 142, 260) and by such special arborescent forms as *Larix americana*, Sequoia, *Pseudotsuga douglasii*, etc. (Penhallow, :04).

From this analysis it appears that there are twelve species of poplar peculiar to the Old World and nine species peculiar to the New World, with one species common to both. From this circumstance it would be natural to conclude that this is essentially an Old World genus, but the slight numerical difference noted would make such a generalization unsafe without confirmatory evidence derived from the paleontological record to which appeal must also be made for an answer to several other questions that have already arisen.

Like the poplars, the willows are a type essentially peculiar to the temperate regions of the northern hemisphere, though they represent adaptation to a greater diversity of climatic conditions and thereby greatly extend the northern and southern range of the family as a whole. With the exception of about 2 percent —an altogether insignificant proportion—they are of a continental character. Nevertheless, in the *S. junghuhniana* of Java, *S. sumatrana* of Sumatra, *S. canariensis* of the Canary Islands, *S. madagascariensis* of Madagascar, and *S. occidentalis* of the West Indies, types which are strongly segregated and localized, their very restricted range is in close proximity to the corresponding vegetation of the continental areas in which they must have had their origin and from which they must have been isolated at a comparatively late period as shown by Wallace ('80). It is these insular forms which are chiefly concerned in the extreme southern extension of the genus, since the six Mexican and eight north African species range considerably farther north. The extreme isolation of *S. humboldtiana* in South America affords at once an illustration of the extent to which dispersal must have been carried in former geological times, and of the potency of the influences which have tended to a greater restriction of geographical area.

Of the one hundred species common to Asia, twenty-four are found within the Himalayan region, while seventy-three are more peculiar to the temperate and boreal regions of Japan, China, Siberia, and Central Asia. In Europe no less than eighty-four species give a range to the genus which extends from the Mediterranean on the south to the polar regions where the very diminutive *S. polaris* with an extreme height of about 3.3 cm., defines the northern limit of growth. In North America, apart from Mexico, seventy-two species similarly extend the genus over a wide range of latitude, their northern limits being defined by the boreal *S. ovalifolia* which also ranges southward on the summits of lofty mountains, as far as Mount Washington in New Hampshire. Ubiquitous species are much more common than among the poplars, and there are no less than 23 which are more or less common to the several continental regions as exhibited by the following synopsis.

Community of Species of Salix.

Europe and Asia	14
Europe and North America	7
Europe and Africa and Asia	1
Asia and Africa	1
	23

In determining these relations, the very pronounced isolation of the Japanese and Himalayan species stands out with great prominence and lends emphasis to the idea of segregation in a previously continuous flora. From the facts thus presented, it is obvious that the willows are preeminently an Old World genus, and that, although their dispersion has a tendency to greater diffuseness than in the case of the poplars, like them they essentially belong to temperate regions, and their tendency is on the whole boreal, rather than austral; so that with respect to the Salicaceæ as a whole, it may be said to be a distinctly temperate and boreal family of wide dispersion within the northern hemisphere, with its center of distribution in Asia where it presumably had its origin. A summary of these geographical relations will serve to make the foregoing analysis more clear.

In the light of these facts it becomes pertinent to ask whether the family as now known represents a type of vegetation which is yet in process of evolution, if it is a side line which has recently attained to the full limit of development and which is therefore terminal, or if it attained the culmination of its development in some previous geological age and is now in a state of decline comparable with that exhibited by the Lycopodiaceæ and the Equisetaceæ. The comparatively recent origin of these plants, if we are to judge them by the standards which have been set by other groups, the general phylogeny of which is fairly well known, would naturally lead us to support the first hypothesis or at least the second, and to reject the third as improbable. But such generalizations are unsafe unless supported by other well established data, and it therefore becomes necessary to inquire somewhat particularly into the nature of the evidence afforded by the geological history of these plants.

Geographical Distribution of the Salicaceæ.

	Old World.									New World.			
	Malaya.	Java.	Sumatra.	India. Himalayan Region.	Other parts of Asia.	Madagascar.	Canary Islands.	Africa.	Europe.	South America.	West Indies.	Mexico.	North America.
Salix	1	1	1	24	73	1	1	8	84	1	1	6	72
	100					10			84	80			
248	194									80			
Percent	0.4	0.4	0.4	9.68	29.43	0.4	0.4	3.22	33.87	0.4	0.4	2.41	29.03
	40.32%					4.03%			33.87%	32.26%			
					78.22%					32.26%			
	Duplications				8.19%					2.19%			
	Total				70.03%					29.97%			
Populus				1	6				6			1	9
22	13									10			
Percent				4.54	27.27				27.27			4.54	40.91
					59.09%					45.45%			
	Duplications				2.68%					1.86%			
	Total				56.41%					43.59%			
Salicaceæ					78.88%					33.33%			
270	Duplications				9.63%					2.58%			
	Total				69.25%					30.75%			

Our knowledge of the fossil Salicaceæ had its origin in the work of Heer upon the fossil plants from the Cretaceous formation of Greenland, through his description of *Populus primæva*. The occurrence of this species in the Kome beds not only afforded the first real evidence of the occurrence of these plants in previous geological time, but it at once served to suggest the essentially primitive character of the Salicaceæ as a whole among Dicotyledons — an idea subsequently strengthened by the discovery of both Salix and Populus in the Potomac formation, as well as in the Kootanie beds of Montana. This idea, then, has persisted to the present day and finds repeated expression in the various treatises on fossil plants, although the acceptance of such a view is not based in any case, upon trustworthy facts derived from a critical comparison of distribution, a knowledge of the phylogeny of the group, or an acquaintance with the anatomy of either recent or extinct species. Paleontologically it is of interest to determine the position of the Salicaceæ relatively to the other families associated with it in the Cretaceous and Tertiary deposits, and for this purpose the flora carefully compiled by Dr. Knowlton ('98) offers the most reliable basis now available. Among forty-five families of angiosperms now known to constitute the flora of the Cretaceous and Tertiary ages in North America, it will be found that, geologically speaking, the Salicaceæ is by no means the primitive group which seems to be implied by the position usually assigned to it, but that it really occupies a position which is the twenty-fourth in a series based upon the percentage ratio of occurrence in the two great geological periods. Such a series has as its lowest member, the Proteaceæ which is preeminently a Cretaceous family, bearing to the Tertiary the ratio of 19 : 0. The same is also true of the Menispermaceæ with a ratio of 17 : 0, closely followed by the Araliaceæ (6 : 0) and the Euphorbiaceæ (2 : 0). At the other extremity of the series we find such families as the Hydrocharidaceæ (0 : 2), Lemnaceæ and Simarubaceæ (0 : 3), Typhaceæ (0 : 4), Onagraceæ (0 : 5), Naiadaceæ (0 : 7), Zingiberaceæ (0 : 17), and the Cyperaceæ (0 : 20), all of which are manifestly typical Tertiary plants. About midway of the series the Salicaceæ are associated with the Urticaceæ with a ratio of 1 : 1.47 and with the somewhat similarly distributed Platanaceæ,

Myricaceæ, Cornaceæ, and Sapindaceæ. There is thus a very strong suggestion (1) that the Salicaceæ is in no sense a primitive family from the standpoint of geological succession, and (2) it is, as a whole, much more characteristic of the Tertiary than of the Cretaceous, more especially as a closer analysis of the one hundred and forty-one known species shows that this rule applies to each of the constituent genera as well as to the entire family, though more conspicuously to the genus Populus than to Salix. Thus we find that the forty-seven Cretaceous species embrace 34 of Populus and 23 of Salix, while the eighty-four Tertiary species embrace 59 of Populus and 25 of Salix, making the ratio of Cretaceous to Tertiary 1 : 1.75 for the former and 1 : 1.09 for the latter — ratios which tend to indicate that these two genera and so the family as a whole, were in process of development even in Tertiary time, a conclusion which is in apparent accord with the recent origin of the family.

Comparison of Cretaceous and Tertiary Floras.

	Seq. No.	Ratio.	Cretaceous No.	Cretaceous Percent.	Tertiary No.	Tertiary Percent.
Proteaceæ	1	19 : 0.00	19	1.09	0.00	0.00
Menispermaceæ	2	17 : 0.00	17	0.98	0.00	0.00
Araliaceæ	3	6 : 0.00	6	0.34	0.00	0.00
Euphorbiaceæ	4	2 : 0.00	2	0.11	0.00	0.00
Passifloraceæ	5	1 : 0.00	1	0.06	0.00	0.00
Asclepiadaceæ	5	1 : 0.00	1	0.06	0.00	0.00
Myoporineæ	5	1 : 0.00	1	0.06	0.00	0.00
Convolvulaceæ	5	1 : 0.00	1	0.06	0.00	0.00
Bromeliaceæ	5	1 : 0.00	1	0.06	0.00	0.00
Casuarineæ	5	1 : 0.00	1	0.06	0.00	0.00
Sterculiaceæ	6	1 : 0.13	15	0.86	2	0.11
Myrsineæ	7	1 : 0.17	6	0.34	1	0.06
Myrtaceæ	8	1 : 0.18	11	0.63	2	0.11
Hamamelaceæ	9	1 : 0.25	4	0.22	1	0.06
Magnoliaceæ	10	1 : 0.31	45	2.60	20	1.15
Thymeleaceæ	11	1 : 0.33	3	0.17	1	0.06
Anonaceæ	11	1 : 0.33	3	0.17	1	0.06
Araliaceæ	12	1 : 0.36	47	2.71	17	0.98
Sapotaceæ	13	1 : 0.50	4	0.22	2	0.11
Lauraceæ	14	1 : 0.56	69	3.98	39	2.25
Vitaceæ	15	1 : 0.61	26	1.50	16	0.92

	Seq. No.	Ratio.	Cretaceous No.	Cretaceous Percent.	Tertiary No.	Tertiary Percent.
Celastraceæ	16	1 : 0.70	30	1.73	21	1.21
Leguminosæ	17	1 : 0.72	32	1.84	23	1.32
Araceæ	18	1 : 0.75	4	0.22	3	0.17
Ebenaceæ	19	1 : 0.76	13	0.75	10	0.57
Ericaceæ	20	1 : 0.94	18	1.03	17	0.98
Bignoniaceæ	21	1 : 1.00	1	0.06	1	0.06
Apocynaceæ	21	1 : 1.00	1	0.06	1	0.06
Alismaceæ	21	1 : 1.00	2	0.11	2	0.11
Platanaceæ	22	1 : 1.26	15	0.86	19	1.09
Myricaceæ	23	1 : 1.29	24	1.38	31	1.79
Urticaceæ	24	1 : 1.47	65	3.70	96	5.54
Salicaceæ	24	1 : 1.47	57	3.29	84	4.79
Cornaceæ	25	1 : 1.50	12	0.69	18	1.03
Sapindaceæ	26	1 : 1.62	24	1.38	39	2.31
Cupuliferæ	27	1 : 1.71	94	5.43	161	9.30
Caprifoliaceæ	28	1 : 1.82	17	0.98	31	1.79
Rhamnaceæ	29	1 : 1.96	26	1.50	51	2.94
Aquifoliaceæ	30	1 : 2.00	9	0.51	18	1.03
Aristolochiaceæ	30	1 : 2.00	2	0.11	4	0.22
Tiliaceæ	30	1 : 2.00	1	0.06	2	0.11
Rosaceæ	31	1 : 2.89	9	0.51	26	1.50
Juglandaceæ	32	1 : 3.00	13	0.75	39	2.25
Liliaceæ	32	1 : 3.00	2	0.11	6	0.34
Altingiaceæ	33	1 : 4.00	1	0.06	4	0.22
Nymphæaceæ	34	1 : 6.00	2	0.11	12	0.69
Gramineæ	35	1 : 6.50	2	0.11	13	0.75
Anacardiaceæ	36	1 : 7.50	4	0.22	30	1.73
Palmaceæ	37	1 : 18.0	1	0.06	18	1.03
Musaceæ	38	0 : 1.00	0	0.00	1	0.06
Eriocaulonaceæ	38	0 : 1.00	0	0.00	1	0.06
Elæagnaceæ	38	0 : 1.00	0	0.00	1	0.06
Droseraceæ	38	0 : 1.00	0	0.00	1	0.06
Rutaceæ	38	0 : 1.00	0	0.00	1	0.06
Polygonaceæ	38	0 : 1.00	0	0.00	1	0.06
Rubiaceæ	38	0 : 1.00	0	0.00	1	0.06
Berberidaceæ	38	0 : 1.00	0	0.00	1	0.06
Piperaceæ	38	0 : 1.00	0	0.00	1	0.06
Hydrocharidaceæ	39	0 : 2.00	0	0.00	2	0.11
Lemnaceæ	40	0 : 3.00	0	0.00	3	0.18
Simarubaceæ	40	0 : 3.00	0	0.00	3	0.18
Typhaceæ	41	0 : 4.00	0	0.00	4	0.22
Onagraceæ	42	0 : 5.00	0	0.00	5	0.28
Naiadaceæ	43	0 : 7.00	0	0.00	7	0.45
Zingiberaceæ	44	0 : 17.0	0	0.00	17	0.98
Cyperaceæ	45	0 : 21.0	0	0.00	21	1.21

The succession exhibited in this table brings into prominence the idea that such families as the Leguminosæ, Vitaceæ, Ericaceæ, Magnoliaceæ, Convolvulaceæ, etc., are inferior to the Salicaceæ which is, in turn greatly inferior to the Cyperaceæ from an evolutionary point of view when considered solely in the light of their geological succession; but the sequence which is thus established is found to be utterly at variance with that usually adopted on the basis of morphological evidence which for obvious reasons must be regarded as the more trustworthy guide. Such discrepancies between the morphological and the geological succession, in our opinion, should not be so great as seem to be suggested by the available data, and no doubt they will diminish as our knowledge of the fossil representatives becomes more nearly complete, but that such discrepancies may be anticipated, and that they are to some extent to be regarded as a normal result of rapid evolution along many diverse lines of development, is a reasonable supposition. The Mesozoic age was a period of very great diversification among plants in consequence of the profound physical changes which had taken place in the atmosphere as well as in the configuration of the surface of the earth, and the fact that as a product of previous development, plants were in a condition to be widely and profoundly influenced by comparatively slight modifications of external conditions. The very great number of families and genera and even species of angiosperms which abruptly appeared in the Cretaceous, presenting as they did types of vegetation wholly unlike those of previous geological periods, indicates that the parental forms must have had their origin in the early Mesozoic and possibly as far back as the Permian, since our acceptance of the general principles involved in De Vries' mutation theory does not permit us to consider as possible, such phenomenal transitions as would be involved in the application of that theory to the case under consideration; while on the other hand all paleontological evidence, as well as the evidence derived from existing types, confirms us in the belief that such highly organized forms could have arisen in the main, only through a long series of transitional forms occupying great periods of time. For the same reasons also, we are led to believe that the great

diversification of the Cretaceous flora must have been initiated at correspondingly early periods, though the general succession of types of which we have knowledge, would indicate that it did not gain full expression until about the time of the Middle Cretaceous. This diversification was no doubt the natural response of vegetation to the profoundly changed physical conditions, chiefly climatic, which followed the close of the Carboniferous age and resulted in a diminution of the carbon dioxide of the atmosphere to about one-twentieth of its original volume with a consequent reduction of atmospheric density; a general purification of the atmosphere whereby it became more readily penetrated by the sun's rays; a lower and less equable temperature with more localized climates, and conditions which, as a whole, were more favorable to a more varied mesophytic type of vegetation. Under such circumstances, involving as they did a more abundant supply of oxygen, the general activities of growth became greater; the transformation of carbon dioxide into assimilable products became proportionately larger; in response to the more favorable conditions of light and air, the foliage became broader and acquired an increased functional capacity; and with the augmentation of capacity for the storage of energy thus made possible, there were increased possibilities of, as well as strong tendencies toward diverse development in which special mutations no doubt played an important part, in response to even comparatively slight variations in environmental conditions. From this point of view it is not difficult to understand that among the numerous offshoots from the main line of descent there would be very varying degrees of activity, and it is readily conceivable that plants of a low phylogenetic position might be held in numerical abeyance for a long time, while others, originating at a higher level but more favorably situated and more capable of responding to their environment, might at once outdistance them in number of species or of varietal forms. Under such circumstances the geological succession might lead to erroneous conclusions as to the true phylogenetic sequence. Such a view is suggested and supported by a comparison of many well known examples among existing species. In this way it would be possible for a relatively superior type of organ-

ization, and one occupying a higher position in the morphological scale, to occupy an inferior position in the geological scale, and thus to appear antecedent to morphologically inferior types.

From the foregoing considerations it is clear that geological data cannot be wholly relied upon to furnish a correct solution of questions bearing upon the evolution of plant forms, and this is especially true with respect to the broad-leaved angiosperms for reasons which will be described more fully on a subsequent page. Interesting as these various speculations may be, as applied to the Salicaceæ they nevertheless lack an essential foundation which can be obtained only by a more searching scrutiny of the family as a whole, and of its component genera, with respect to their more detailed distribution in Cretaceous and Tertiary time, as well as at present.

Nowhere has it been possible to obtain so complete a record of the Cretaceous flora as from the exposures to be met with in Greenland and the United States, and the systematic way in which the various horizons have been worked out, affords a very satisfactory basis for a knowledge of the geological succession of species and genera. In his studies of the Cretaceous flora of Greenland, Heer found that out of a total of 88 species from the Kome beds, only 5.68 % were Monocotyledons, while the Dicotyledons were represented solely by *Populus primæva* to the extent of 1.14 %. In the Cenomanian flora of the Atane beds, there was a remarkable increase of Dicotyledons amounting to 50.09 % in a total of 177 species; while from the Patoot beds of the Senonian, 59.48 % were Dicotyledons out of a total of 116 species, thus showing a marked development of this type of plants toward the close of the Cretaceous. This ratio between the three divisions of the flora also appears to extend very largely to the Salicaceæ in particular, with respect to which we find 27.40 %, 42.40 %, and 30.10 % respectively for the three horizons. An analysis of the family, however, shows that this relation does not altogether hold in detail for the individual genera. Thus in Salix the percentages are 41.40, 41.40, and 17.20 which approximates to the results for the family as a whole with respect to the very evident falling off in the Upper Cretaceous. Nevertheless this is much more marked in the

genus than in the family, and suggests that the former is in process of decline, a conclusion which seems to be directly opposed by the evidence afforded by the ratio of extinct and living forms. Populus gives 18.10%, 43.10%, and 38.60% for the three horizons with a maximum development in the Middle Cretaceous.

Distribution of Salicaceæ in Cretaceous of United States.

Salix.

	Lower.	Middle.	Upper.
Salix stantoni			×
mattawanensis		×	
meekii		×	
protæfolia	×	×	
" *flexuosa*	×	×	
" *lanceolata*		×	
" *linearifolia*		×	
" *longifolia*		×	
cuneata		×	
deleta		×	
hayei		×	
inequalis	×		
membranacea	×		
nervillosa		×	
newberryana	×		
pacifica			×
purpuroides	×		
sp.	×		
sp.			×
sp.	×		
sp.			×
sp.		×	
sp.			×
Saliciphyllum ellipticum	×		
longifolium	×		
parvifolium	×		
Species 26	11	12	5
Percentage distribution	42.3%	46.1%	19.2%

Distribution of Salicaceæ in Cretaceous of United States.

POPULUS.

	Lower.	Middle.	Upper.
Populus berggreni	×	×	
hyperborea		×	
stygia		×	
mutabilis	×		
lævigata			×
arctica			×
problematica			×
obovata			×
melanarioides			×
wardii			×
mutabilis ovalis ?			×
apiculata	×	×	
aristolochioides		×	
auriculata	×		
cordifolia		×	
elliptica		×	
harkeriana		×	
latidentata			×
kansaseana		×	
longior			×
leuce		×	
microphylla		×	
potomacensis	×		
protozadachi			×
rectinervata			×
rhomboidea			×
trinervis			×
sp.			×
sp.			×
sp.			×
Populites tenuifolius		×	
cyclophylla		×	
elegans		×	
lancastriensis		×	
litigiosus		×	
microphyllus		×	
probalsamifera			×
sternbergii		×	
winchelli		×	
Populophyllum crassinerve	×		
hederæforme	×		
reniforme	×		
Species 42	8	19	17
Percentage distribution	18.1%	43.1%	38.6%

Again, comparisons with existing species are instructive. If all the various forms now recognized are to be regarded as valid species, then it would appear that the genus Populus must have attained to its full development in the later Cretaceous or possibly early Tertiary time, since when it has been in a process of slow decline, or at least it has made no substantial progress. A very noteworthy feature of such comparisons appears in the somewhat abrupt increase among the Salicaceæ in common with other Dicotyledons, in the Middle Cretaceous, especially in the Dakota group. A ready explanation of this phenomenon on purely botanical grounds might be found in the facility with which hybridization gives rise to very stable forms, and it is in all probability true that such hybridization is accountable in large measure for the multiplication of forms or species in past times as it is known to be at the present day; but to the geologist this would probably not afford an adequate reason, since he recognizes the important extent to which "accidents" as determined by exposure of strata, methods of preservation, etc., constitute very definite and often controlling factors in the number and kinds of plants which may be yielded by a given formation, in which sense Dr. Knowlton has observed "that though some types of the Cenomanian, as shown by the leaves of the Dakota group, generally remain distinct and plainly defined in the vegetation of some of the subsequent formations, the chain of evidence is not always continuous. A number of these, for example, still remain unrecognized in the Upper Cretaceous, though present in more recent strata of the Laramie or of the Tertiary. We know very little as yet of the flora of the Senonian or of intermediate stages between the Dakota and the Laramie groups. But judging from recent discoveries in Wyoming, Montana, Canada, and Vancouver Island, we have been able to recognize in the scanty materials obtained, the presence and therefore the persistence of some of the primitive or more ancient types, and it is most probable that further research will complete the evidence of the persistence and representation of the types of the Dakota group up to the Laramie, as clearly as it is observable in this flora and through the different stages of the Tertiary to the present time (Lesquereux, '92).

We are now led to ask: "What is the nature of the evidence, with respect to the particular form and value of the plant remains, upon which our knowledge of the geological succession is based?" Of the internal structure of the fossil Salicaceæ we as yet know nothing, for with the exception of a few specimens from the Pleistocene, the wood of these plants has not yet been brought under examination, and we are therefore denied one of the most definite means of distinguishing with certainty not only the various species and genera, but also the relations which the members of this group bear to one another and to other groups. That fragments of the stems of willows and poplars must sooner or later be found and brought under examination, is altogether probable, and as an essential provision for the proper recognition of the various species at such times, it is important that accurate diagnoses of existing species should be made.

The only evidence at present available for the recognition of members of the Salicaceæ, is in the remains of their leaves which are too often found in a very fragmentary condition and otherwise unsatisfactorily preserved. Recalling the extent to which hybrid and variable forms occur in this family, and the often extreme differences which may arise in the same species as shown by Ward ('88), Holm ('90, '95), Berry (:01–:03, :02a, :02b), and Penhallow (:04), it is readily seen that the numerical distribution of these leaf forms in geological time cannot be regarded as affording an accurate basis upon which to found a knowledge of succession, and such remains can never be of more than approximate value with reference to an exhibition of the most general relations. Under these circumstances, as pointed out by Holm ('95) some years since, "a careful study of the recent flora is absolutely necessary when it is desired to identify fossil leaves with even an approximate degree of correctness. The plant must be studied as it stands amidst the surroundings to which it has adapted itself and which its leaves reflect." It is altogether probable that a more complete and detailed knowledge of the Salicaceæ would show that the present forms which are recognized as distinct species, in reality represent, in many cases, only variations of the same species.

This idea is emphasized more particularly in the case of the willows by the observation that *Salix protæfolia* has no less than four variants, or five forms in all, as presented by the generally accepted specific type and the varieties designated as *flexuosa, lanceolata, linearifolia*, and *longifolia* — forms which are all characteristic of the Dakota group, though *S. protæfolia* and *S. protæfolia flexuosa* are also found in the lower Cretaceous. We therefore find that so far as the geological evidence alone is concerned, it throws no light whatever upon the possible ancestry of these plants, it affords absolutely no clue as to their relations to other groups of plants, and it gives no very trustworthy information as to their present position in the scale of development. But when such evidence is taken in conjunction with that derived from a knowledge of the family as at present existing, the following conclusions appear to be fully justified:

(1) The Salicaceæ as a whole is an Old World family with its probable center of distribution in southeastern Europe and Central Asia.

(2) It is a family with a strong tendency to a boreal habit which has become more definitely emphasized since Tertiary time.

(3) The present tropical and subtropical members of the family, probably represent the relics of a wider dispersion in Cretaceous and Tertiary time, which have been isolated and localized as the result of more recent contraction in the family as a whole.

(4) The family at present affords strong proof of a temperate climate. In Cretaceous time it was compatible with a much warmer climate than at present, as indicated by the survival of tropical and subtropical forms; but changes more recently effected, have made its tendencies boreal rather than tropical.

(5) The family had but a feeble development in the Lower Cretaceous, but become greatly augmented in the Middle Cretaceous.

(6) It is a family which may be regarded as still in process of development.

(7) The process of evolution is chiefly expressed in the genus Salix which shows a very great increase since the Middle Cretaceous.

(8) The process of evolution is less definitely expressed in the genus Populus which shows but little advance since the Middle Cretaceous, and it may possibly be regarded as having attained the culmination of its development.

While it is impossible at present to discuss the anatomy of these plants in the light of their ancestral forms, the study of existing species may serve an important purpose as a working basis for future paleontological research in this direction, and it may eventually prove to be the key which shall unlock the door now concealing important records of the past. In this sense it is necessary to formulate a theory of possible descent as a working hypothesis, and this can be obtained only through a detailed study of the anatomy of the Salicaceæ in comparison with what has already been ascertained to represent certain laws of development in the gymnosperms. This hypothesis may be stated briefly before proceeding to a discussion of those anatomical details which may lend it support.

A comparison of the ferns, arborescent pteridophytes such as Calamites and Lepidodendron, and the arborescent types of gymnosperms and angiosperms, shows, in general terms, that the so called wood increases in proportion to the requirements of mechanical support. This latter is usually met by the disposition of the tissue in such a manner as to afford the most effective resistance to external stress, and it is therefore disposed in monostelic stems, in the form of a definite cylinder which constitutes the secondary xylem structure. It is also an essential feature of the same law, that the secondary xylem should be in all cases radially external to the protoxylem, and that its augmentation in secondary growth of the stem must always arise in radial succession.

In the polystelic ferns where the secondary xylem consists almost wholly of vessels and the wood elements are numerically subordinate, these latter are distributed among the other elements of the xylem and do not form a specialized mechanical region. Such strengthening as these plants require, is accomplished in the first instance by the sclerenchymatous bundle sheath, and secondarily by the more general conversion of the fundamental tissue into hard sclerenchyma. It is similarly

impossible to compare such plants in any direct way with the polystelic angiosperms in which the mechanical tissue generally encloses the vascular structure in a more or less definite sheath which exhibits a more or less clearly defined relation to mechanical stress. While, therefore, for the purposes of our present argument, it is impossible to introduce exact comparisons with any of the polystelic forms of stems, we must nevertheless conclude that the secondary wood, in whatever form it may be disposed, must be regarded as differentiated to meet mechanical ends as shown by Williamson ('71) in his various elaborations of the Calamitean structure and as more recently stated by White (:05); but a knowledge of the relations existing between the protoxylem and the secondary xylem requires a more critical examination in detail, in order to determine the course of development which has given to the gymnosperms and the dicotyledonous angiosperms, the peculiar structural aspects distinguishing them respectively. This will constitute the subject of a special paper at a future date, and in the meantime it will serve our present purpose to state briefly the fundamental conceptions which form the essential features of our hypothesis. In order to make our point of view more clear, it will first be necessary to state concisely what has been shown to hold true of the gymnosperms with respect to the evolution of the secondary vascular structure and its economic aspects in relation to the requirements of support, as well as its physiological *rôle* in the conveyance of nutrient fluids.

The origin of the gymnosperms in the Cycadofilices, or at least a portion of them, is now generally accepted as an established fact. The essential starting point for the evolution of the vascular cylinder is therefore to be found in the scalariform and spiral vascular elements of the Cycadofilices or their filicinean ancestors which constitute the entire vascular bundle of those plants, and which, in the gymnosperms, constitute the protoxylem structure only. The relatively greater extent to which the mechanical elements are developed in some of the Cycadofilices and in the Cycadaceæ as a whole, is in direct response to the somewhat more arborescent tendency of these groups as particularly expressed in certain genera; while the fact that they do

not in any case attain to the extreme preponderance noted in the Cordaitæ and Coniferæ, etc., is precisely in harmony with the general approximation of the Cycadaceæ as a whole to their filicinean ancestors and the lack of need for that peculiar form of mechanical support which is demanded by trees of large size, and which is provided in all the arborescent forms of the seed plants. With these statements it will be unnecessary to follow the Cycadaceæ in further detail, but rather to consider the course of events in the more arborescent Cordaitales and Coniferales where the analogy with the angiosperms is closest. It is now a well recognized fact that the protoxylem of the gymnosperms constitutes a transition zone within which peculiar and often somewhat remarkable evolutionary changes take place. The protoxylem or transition zone is a region peculiarly sensitive to the controlling influences of environment, and its response is so immediate as to give rise to structures of a very diverse nature. This has been shown to be true of the Cycadaceæ (Penhallow, :04c) to a notable extent, while it is no less prominent in the Cordaitæ, both of which groups are of a recognized primitive character among gymnosperms and stand in somewhat close relations to their Cycadofilicinean ancestors. But a very important difference exists between these two groups with respect to the survival of the protoxylem and the precise composition of the secondary wood. In the Cycadaceæ the growth of the stem in annual increments involves the complete repetition of the entire xylem structure and the formation of secondary growth in a manner which is to be met with in no other group of gymnosperms. The growths of successive years are not immediately joined to one another and therefore conterminous, but they are separated radially by very definite zones of fundamental tissue of the original cortex. In each zone of growth we recognize spiral and scalariform elements of a transitional form, together with tracheids bearing bordered pits and forming the secondary xylem. These tissue regions are disposed precisely as in the growth of the first year; they bear the same relations to one another both in position and in development, and in each case they perform the same functions as in the initial zone. From this it follows that there is a complete regeneration of the

xylem structure in all its parts, with each year of growth, and it is not unreasonable to consider that the same structural regions should be designated by the same terms wherever they may occur. In this sense, therefore, we should recognize the primary growth, as well as the secondary growth of each subsequent year, as composed in each case of protoxylem and secondary xylem. The protoxylem survives throughout the entire life of the plant.

In the higher gymnosperms as also in the Dicotyledonous angiosperms, the case is quite different. In them the rings of secondary growth are in all cases united to and conterminous with the structure of the preceding year, and under these circumstances, as well as for reasons which will again be referred to, the protoxylem experiences complete suppression and does not reappear after the growth of the first year. In this case, then, the primary growth consists of protoxylem and secondary xylem, while the secondary growth consists altogether of secondary xylem, and in this we find one of the most important structural distinctions between the Cycadaceæ and all other types of gymnosperms, bringing the former into the closest relations with their ancestral forms and removing the other gymnosperms with the Cordaitales as the basal member of the series, to a distinctly higher phylogenetic position.

In Cordaites, reduction has been developed to such an extent that the protoxylem no longer forms a constituent part of the annual rings of growth, since it is wholly confined to the growth ring of the first year where it constitutes a region of very considerable radial extent, gradually merging with the secondary xylem in such a way that there is no sharp line of demarcation between the two. Within this zone graduated transitions are a well known and remarkable feature: but it is to be noted that in all these respects there is a further removal from the ancestral forms and a distinct development along those lines of evolution which eventually issue in the characteristic structure of the higher Coniferales. As these latter are reached, it is to be observed that there is a constantly greater reduction in the radial extent of the transition zone, and the intermediate structural variations which it presents, until, eventually, it becomes

only a few elements broad, and there is an abrupt transition from spiral or scalariform structures to the tracheids with bordered pits. We may therefore consider that in all the higher Coniferales, the structural type is fixed to such an extent that evolutionary aspects are no longer presented.

The changes initiated in the transition zone relate to the evolution of the modified vessels or tracheids which constitute the bulk of the structure in the vascular cylinder. In the development of such tracheids their capacity for the movement of the transpiration current is not lost, except in special cases, but it is rather modified with reference to the total extent of the conductive tissue and the somewhat low rate at which the transpiration current is required to move. Each tracheid is provided, among the primitive forms, with bordered pits on both the radial and tangential walls through which a somewhat ready and direct transverse diffusion is provided for, while diffusion in a longitudinal direction can never be otherwise than indirect and therefore at a relatively slow rate. With an advance in organization, the bordered pits tend to disappear from the tangential walls where they survive only at the ends of tracheids or in the summer wood, the latter distribution being necessitated by the peculiar radial compression which such cells experience. It follows from this that in all the higher types of the gymnosperms, there is a greater degree of restriction imposed upon the transverse diffusion and through the latter, also a further restriction of the longitudinal diffusion. Whatever deficiency in circulation is developed through these structural alterations, compensation is provided by the great extent to which such tissue is formed; and that the tracheids effectively discharge the duty imposed upon them in this respect is manifested in their complete replacement of the true vessels of the protoxylem, as well as in the fact that those of the heart wood may resume their functional capacity for the conveyance of nutrient fluids when the sap wood becomes incapacitated through desiccation or other causes (Goodwin, '88). Such restricted movement of the transpiration current is in direct accord with the generally xerophilous character of the gymnosperms, whether this latter be correlated with absolute deficiency of water supplies or a

temperature which is so reduced as to permit of but slight absorbent activity in the roots; and so it is found that the peculiar form of the conductive tissue is really developed in correlation with the environment of the plant. But it is to be observed that the protoxylem is called upon, in the course of its development, to meet another essential factor in the life of the plant; namely, its ability to withstand external stresses of various kinds and through this the establishment of an upright position for the organism. It is quite conceivable that this requirement might be met by the evolution of a specialized form of element from the meristem without reference to the prior development of vessels, and this might be looked for in the angiosperms, but such has certainly not been the case in the gymnosperms. The somewhat slight modification, and in some senses the reduction which the vessels of the protoxylem have undergone in their adaptation to the movement of the transpiration current, has also permitted of their immediate adaptation to the purposes of mechanical support. They have therefore become more fibrous in character, while at the same time their walls have become sensibly thickened and in corresponding degrees more fully fitted to withstand stress. It is thus evident that two forms or directions of development have been combined in the same element, and it is no doubt also true that the peculiar form of the pits is in itself a direct resultant of such a combination development, since it has been shown that the bordered pit represents a localized area which has been left over in the otherwise general thickening of the wall in response to the requirements of intercellular circulation. The reduction of the bordered pit and its frequent elimination from the wall of the tracheid, especially in the summer wood, is in direct harmony with these statements and represents the relative predominance of requirements relating to circulation or mechanical support at different periods of growth and under special conditions of environment. So far as we know at present, no further modification of the tracheid than that presented in existing species is possible to the gymnosperms, and this particular line of evolution may therefore be regarded as completed in that group.

Our hypothesis as applied to the angiosperms on analogous

lines of development, is based primarily upon the idea that the well marked differentiation of conductive and mechanical tissue which is everywhere so prominent a feature of the arborescent forms, extending in a less conspicuous way to herbaceous types, cannot be secondary to and therefore derived from that special course of development which is so fully expressed in the wood of the gymnosperms; but that it must have had its origin in antecedent or contemporaneous types, and that it must in consequence represent a wholly distinct line of evolution arising in response to very dissimilar environmental conditions.

In the angiosperms, representing as they unquestionably do, a higher type of development, there is, even among their most primitive forms, a further removal from the ancestral type, and as presented by the Dicotyledons, they must be regarded as essentially occupying the same general plane of development as the higher Coniferales, inasmuch as they are all characterized by a transition zone consisting of but few protoxylem elements; and the passage from these latter to the elements of the secondary xylem, whether vessels or wood cells, is abrupt and direct. Like the higher Coniferæ, therefore, they represent types in which the structure of the transition zone is essentially fixed, and under normal conditions of development the formation of the secondary xylem is, from the first, in direct response to a fixed habit. We may nevertheless expect that under exceptional conditions of growth such as would involve reduced vigor, and also such as through an induced habit of growth would eliminate very largely the special necessity for mechanical support, there would be a more or less marked tendency in the direction of reversion to primitive structural conditions. Such reversions might be expected to show a distinct augmentation of the transition zone with the appearance of transitional forms of the anatomical elements, which would then diverge from the protoxylem in the particular directions imposed by the natural fixed habits of the genus or species as the case might be. Alpine forms of otherwise large trees might be expected to afford the most favorable material for the exhibition of such reversions in consequence of (1) the greatly reduced form and size of the plant consequent upon its unusual environment, and (2) the fact that

a dwarfed or even prostrate habit of growth no longer imposes those demands for rigid support which are from the first a prime necessity of the strictly arborescent forms. Precisely such conditions and precisely such results are to be met with in *Salix cutleri* Tuckerm., of which a more detailed account will appear on a subsequent page.

In the development of the secondary xylem of angiosperms, two distinct lines of evolution are to be observed — the one leading to the exaggerated development of vessels, the other leading to the exaggerated development of mechanical tissue, the two being balanced with respect to the relative excess of requirements on the one side or the other. Confining our attention in the first instance to the vessels, it is found that in their evolution from the elements of the protoxylem, these latter deviate more widely from a fibrous form so that their products become broader and either actually or relatively shorter, while the terminal walls often disappear altogether, thus giving rise to tubular structures of indeterminate length. The walls of such vessels are somewhat modified by secondary thickening, though relatively to their usually great breadth this is not more than is demanded by their own need for support, and it cannot be regarded as an essential factor in the strength of the organism as a whole. Like the tracheids of the Coniferae, the walls are characterized by the presence of bordered pits which differ in two very important respects from the similar markings which generally characterize the higher gymnosperms. They are always multiseriate and chiefly hexagonal, though as shown in the Salicaceæ, they may become more distant and definitely rounded; they also occur on both the radial and tangential walls. In both of these features the vessels show the survival of primitive characteristics which are only partially represented among the Cordaitales, and which indicate that the ancestral forms must be looked for among the Cycadofilices where they are of well known occurrence, or else among some other group of similar structural characteristics, but of which we have no present knowledge. Now the angiosperms are essentially all broad-leaved plants adapted to a distinctly mesophytic habit, and it is therefore to be concluded that the transpiration current not only moves with greater rapidity

as compared with the Coniferæ, but that it is of greater volume and requires a correspondingly more capacious channel; while such channels must also be direct and involve fewer impediments to free circulation in a longitudinal direction. These requirements are met by the large, transverse volume of the individual vessel; by the great multiplication of vessels so characteristic of Catalpa, Salix, Populus, etc.; by their repetition in the secondary xylem of each year's growth, and in the provision for very free longitudinal movement of fluids as expressed in the sieve-like terminal walls, or in the complete obliteration of such interposed septa. Although such vessels retain their capacity for the conveyance of the nutrient fluids for a long time, *i. e.*, several years, they eventually become functionless, often through the formation of extensive thyloses as in the Catalpas, members of the Salicaceæ, Quercus, etc., and in general terms the functional capacity of the vessels cannot be restored when so lost, while under certain circumstances, the development of thyloses may assume a definitely pathological aspect (Watt, :01). From the observations thus far made, it is evident that the particular evolution of the protoxylem which results in the formation of such vessels, provides elements which are solely concerned in the movement of the transpiration current, and which have, as it were, appropriated this function in such an exclusive sense as to eliminate it from all other structural elements of the xylem, so that these latter are thereby left free to develop in the most responsive way under the special influence of other requirements.

We may now ascertain the special features which serve to distinguish the second course of evolution from the protoxylem, already referred to. The excessive development of the conductive tissue tends to diminish the general strength and call for the formation of purely mechanical elements to an extent otherwise unnecessary. This factor operates, therefore, to emphasize the divergence of the two lines of structural evolution, giving greater prominence to the conductive elements on the one hand as already shown, and on the other hand to the mechanical elements. Certain of the protoxylem elements, otherwise potential vessels, are diverted in growth, and instead of expanding, they contract with a correspondingly greater development of the secondary wall, and assume a strictly fibrous form. This necessa-

rily leads to the greater simplification of the pits which rarely retain the bordered form but become simple perforations and commonly disappear altogether. Concurrently with these changes, the progressive increase in the thickness of the wall eventually leads to a more or less complete obliteration of the original cell cavity; and while all these varied changes have a profound bearing upon the ultimate strength of the general structure, they at the same time operate to eliminate completely even such slight capacity for conduction of fluids as the elements may have had in their earlier stages of development.

The hypothesis as thus presented, is suggested at the present time in view of the many facts which have come under observation during the progress of studies bearing more particularly upon the anatomy of the Coniferales as elsewhere recorded (Penhallow, :04c), and because of the need of some working basis from which we may view the anatomy of the Salicaceæ, and upon which we may erect a possible point of departure for an interpretation of their phylogeny. The first real test of the validity of this hypothesis will be made on the basis of data to be derived from a study of the Salicaceæ as recorded in subsequent pages. If it proves to have the support of observed facts it will then be necessary to supplement it with the further hypothesis that the angiosperms as a whole had their origin in some generalized type, possibly identical with or at least nearly related to the Cycadofilices; and in any event we can hardly agree with the suggestion of De Vries (:05) that the Monocotyledons "are obviously a reduced branch of the primitive Dicotyledons," since our own investigations not only fail to lend support to such an idea, but they tend to establish evidence to the contrary, and to the effect that while the two may possibly have had their starting point in a common, generalized type, they nevertheless represent two distinct lines of descent. On the basis of such a hypothesis, we should reasonably expect to find in the early Mesozoic and Permian, and possibly even in the later Carboniferous, transitional forms which would carry the angiosperms back to some of the later but less highly specialized types of the Cycadofilices.

(*To be continued.*)

DEVELOPMENTAL STAGES IN THE LAGENIDÆ.

JOSEPH A. CUSHMAN.

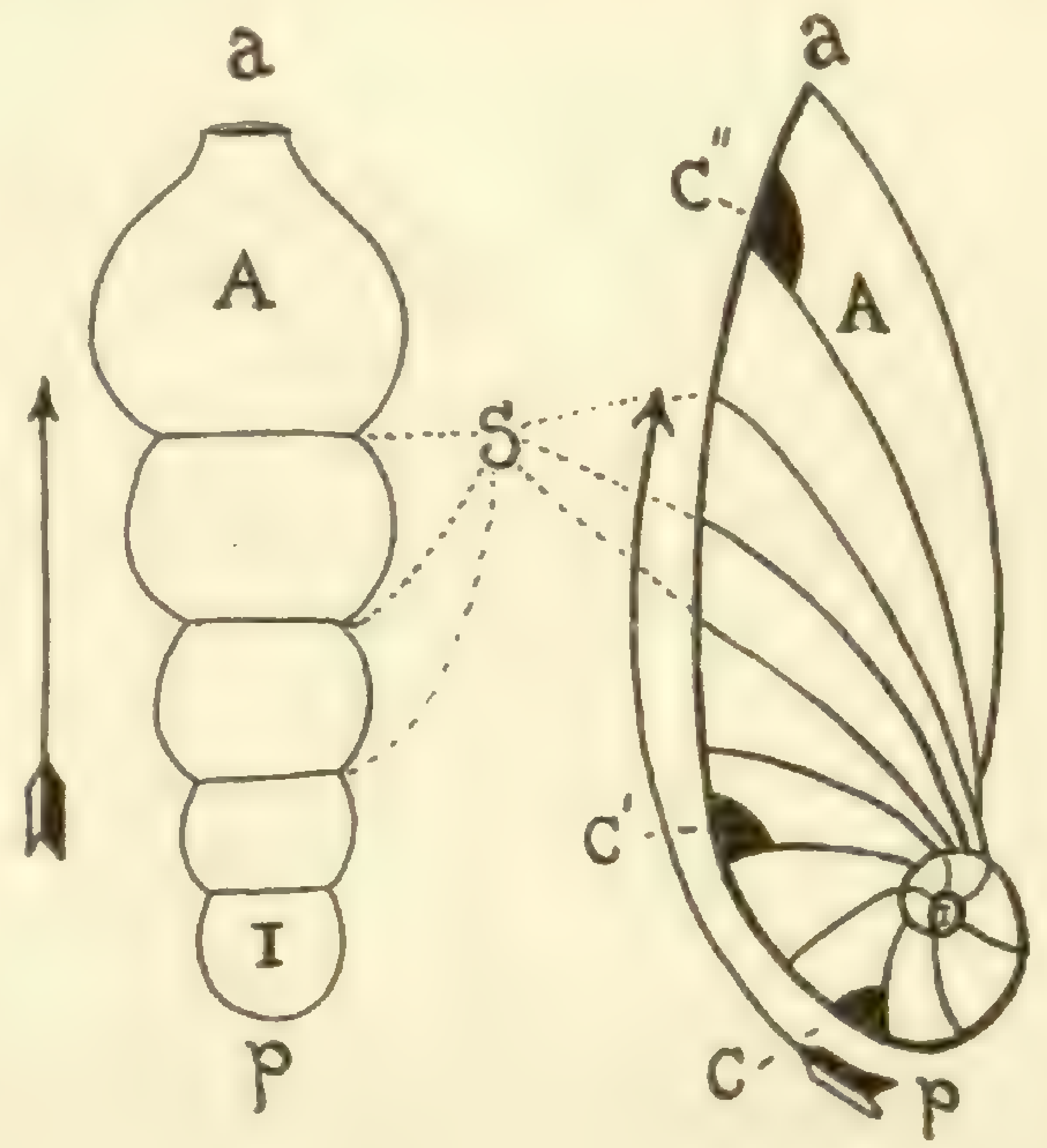
THE Foraminifera present certain characters which make their study different from that of almost any other group of the animal kingdom. They are unicellular animals, but secrete a shell which in many cases has a considerable degree of complexity and shows marked stages in development. Their geological history is very long, for representatives are found in the Cambrian sedimentary rocks and more or less in intermediate horizons to the present time. At present, the Foraminifera are found, as a rule, in the deep waters of the oceans and extending toward the shores. Some twenty or more of the species occur as pelagic forms. In these animals the intermediate steps between extreme generic and specific forms are so well filled in, even in the living species, that some authors have regarded them all as simply variations of a single species. This is altogether too extreme a view. Intermediate species may be expected when the habits, environment, and reproductive characters of the animals are taken into consideration.

That the laws of development enunciated by Professor Alpheus Hyatt may be applied to this group, is shown in the following discussion. These laws have hitherto been applied only to groups of the Metazoa but as will be shown in the present paper they are equally applicable to another group of the animal kingdom, the Protozoa.

In tracing the development of Foraminifera where young individuals can be obtained, the relations are usually made out with ease. In the absence of young individuals the most reliable method is the study of sectioned specimens, since many species which are coiled, cover all traces of the younger portion externally by their later growth. Sectioning, in many cases, is the only method by which, from adults, the characters of the early growth may be seen in their true relations.

Definition of a few Terms.

The following terms as defined, some of which are new, are convenient in the description of the structure of the shell of Foraminifera. The succeeding divisions of the shell are usually spoken of as chambers, the one first formed being the initial chamber (*I* in Figs. 1 and 2) and the last one built in any given specimen, the anterior chamber (*A*). The initial chamber which will be shown to have a decidedly phylogenetic bearing in the group is here given a distinctive name — the ***proloculum***—to correspond with the term applied to the embryonic shell of other groups already worked out in the Metazoa. The ends of the shell as a whole are called anterior (*a*) and posterior (*p*). The walls of the chambers are called anterior and posterior walls according to their individual position in relation to the direction of growth. The line of contact made by the joining of a succeeding to a preceding chamber is called a suture (*S*). In coiled forms the outer border formed by the sum of the distal portion of the walls of succeeding chambers is called the peripheral margin. The angle between the suture and the distal wall of the next succeeding chamber in coiled forms is called the angle of curvature for that portion of the peripheral margin. These angles are shaded at *C*, *C'*, *C''*, to show the decided differences that the angle may assume.

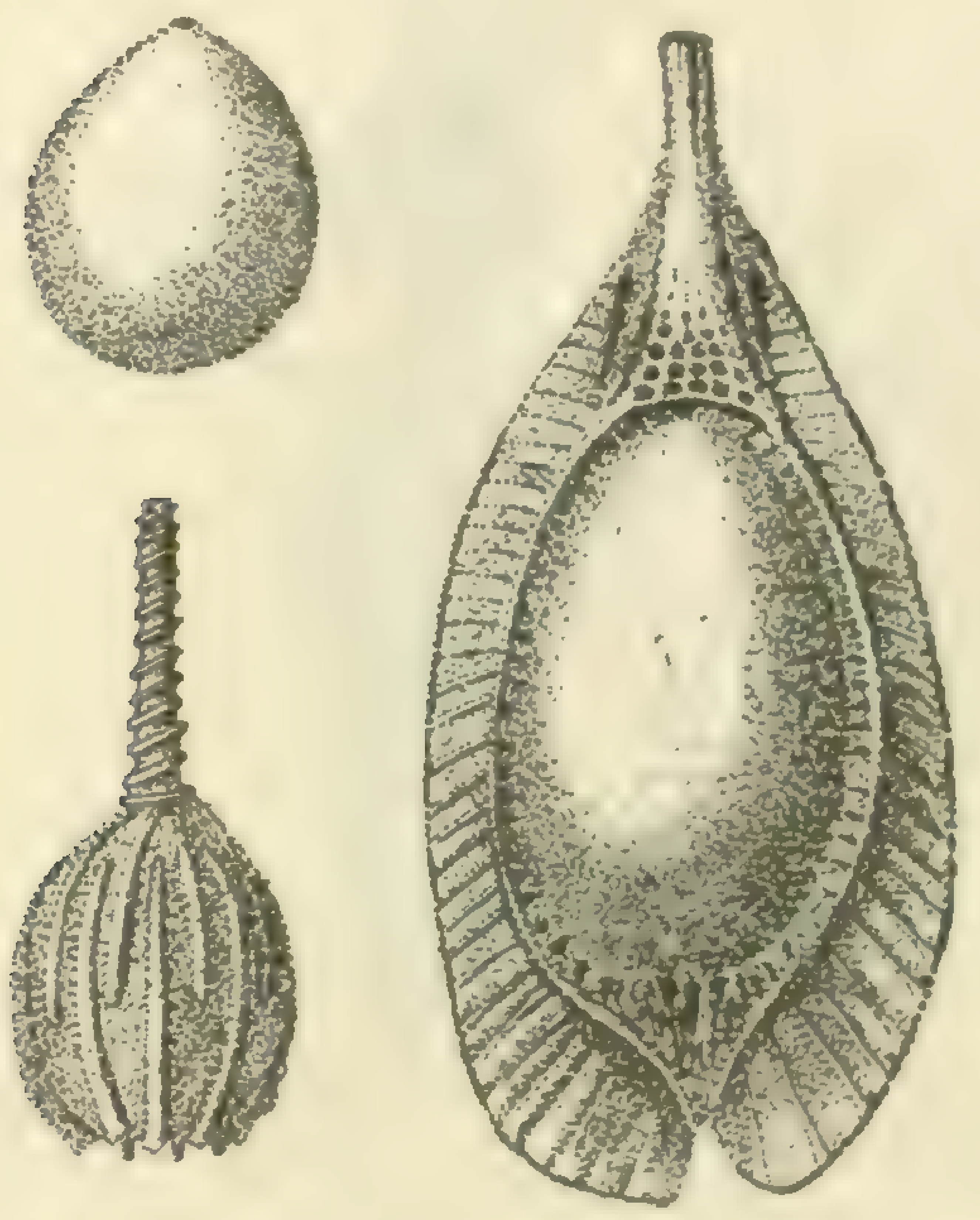


1 2

Fig. 1.—Nodosaria. Fig. 2 — Uncoiled form of Cristellaria. *A*, anterior chamber: *I*, initial chamber or proloculum: *a*, anterior end; *p*, posterior end. Arrows show the direction of growth: shaded portions indicate the angle of curvature at *C*, *C*,' *C''*; *S*, sutures.

DEVELOPMENT OF TYPICAL SPECIES OF VARIOUS GENERA.

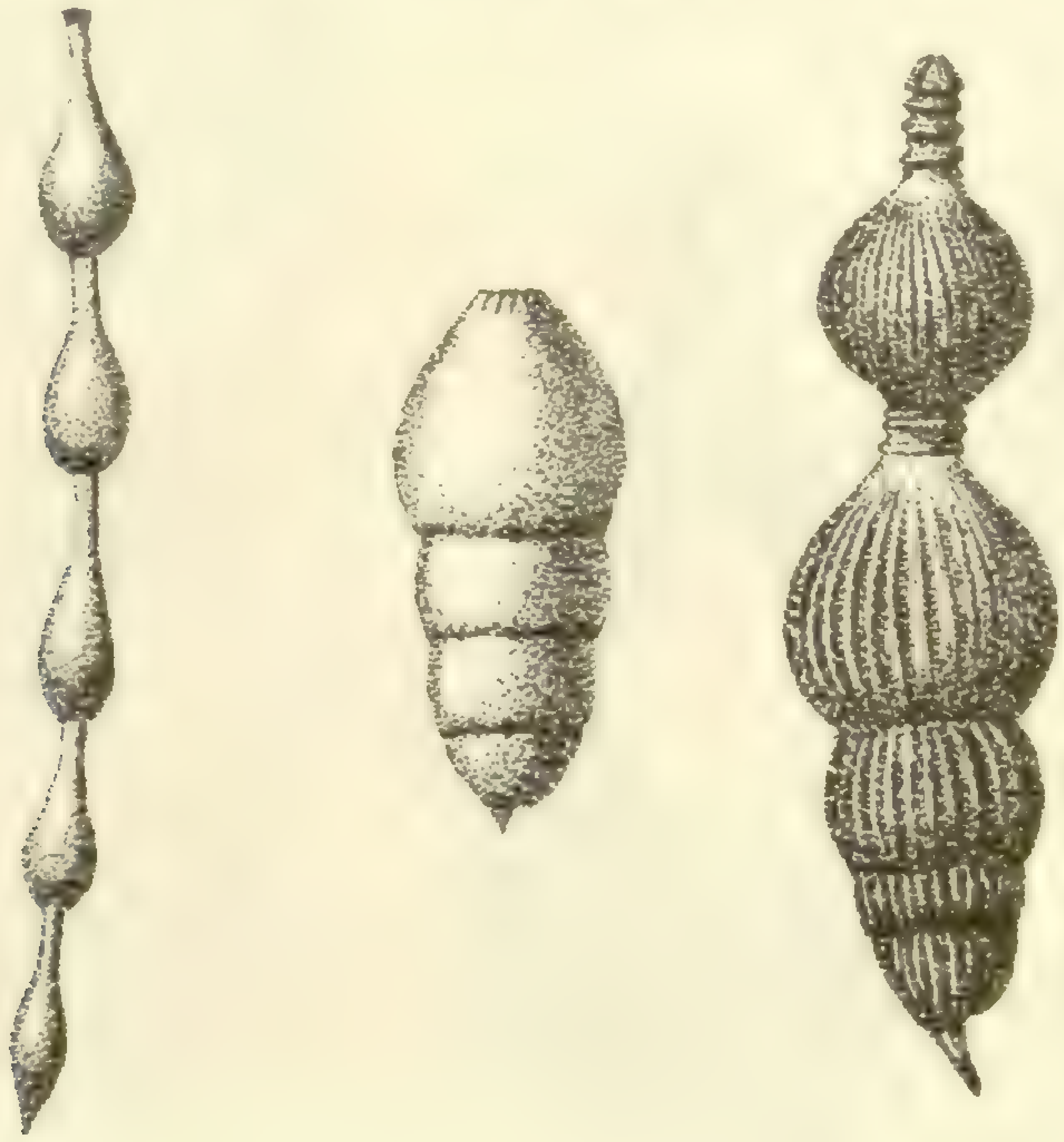
Lagena.— This genus represents the simplest condition seen in the family under discussion. In its geological history it can be traced from the Silurian to the present time. It is monothalamous or single-chambered (Fig. 3). The species very commonly develops a neck at the anterior end (Figs. 4, 5). The variation in forms of ornamentation is very remarkable and includes costæ, reticulate patterns, knobs, and bosses or broadly expanded wings of shelly material, but the underlying character of the chamber is always that of a simple flask-like form or a modification of it. This simple chamber represents the completed development of this genus, which is the only one of the family that has the single-chambered character. As it is the simplest form in the family and as all the other genera of the family start off with a simple chamber which is comparable to it, Lagena may be taken as the radical from which other genera of the family may be derived.


3 4 5

FIGS. 3–5.—Three species of Lagena showing the great differences in ornamentation that are found in the group. Fig. 3, *Lagena globulosa* Montagu, a smooth type; Fig. 4, *L. sulcata* W. & J., var. *interrupta* Williamson, a costate type; Fig. 5, *L. formosa* Schwager, a type with expanded wing-like growths. (Figures after Brady.)

Nodosaria.—This genus in its typical form consists of a linear series of Lagena like chambers, the posterior wall of each newly added chamber overlapping the anterior wall of the preceding one. The initial chamber or proloculum is comparable in character to the adult Lagena but the addition of the second chamber in Nodosaria shows that it is developing beyond the single-

chambered Lagena condition. The succeeding chambers add no striking characters in development further than that given by the second except in features of ornamentation which is a secondary character. The chambers of the linear series may be more or less closely overlapping (Figs. 6, 7) and this character



6 7 8

FIGS. 6–8.—Three species of Nodosaria showing the difference in the amount of overlapping, and in Fig. 8 the Lagena-like last chamber. Fig. 6, *Nodosaria pyrula* d'Orb.; Fig. 7, *N. radicula* Linn.; Fig. 8, *N. scalaris* Batsch (Figures after Brady.)

of overlapping may vary with the age of the individual as shown in progressively added chambers of *Nodosaria scalaris* var. *seperans* Brady (Fig. 8). They may also be variously ornamented according to the species but the linear series of chambers is always the essential character. Very often the last-formed or final chamber is more distinctly separated from the preceding ones and is decidedly Lagena-like (Fig. 8). Therefore at the end of growth representing old age or senescence, a chamber may occur which is closely comparable to the first stage of development in the young of the same individual or to the simpler genus Lagena. The stages of development of Nodosaria from young to old age may be expressed by a formula using the initial letters of the genera represented, as L + N + L.

Cristellaria.—The initial chamber or proloculum of Cristellaria, as in the other genera of the family, is simple and Lagena-like (Pl. 1, Fig. 6). The second chamber is added obliquely (Pl. 1, Fig. 7), as in some species of Nodosaria, and at this stage simply reveals the fact that it will not be a Lagena nor any of the straight Nodosarian forms. The third chamber of Cristellaria adds a decidedly new character. Instead of continuing on as in Nodosaria, it extends back on its inner margin so as to come in contact with the proloculum or initial chamber initiating the feature of coiling (Pl. 1, Fig. 8). In Cristellaria this coiled character is maintained throughout further growth in typical species as in Figs. 9, 18, 19. In further growth the shell may take on a flattened form as in *Cristellaria compressa* d'Orb., or may later take on a loose-coiled, or straight form of growth as in the species *C. siddalliana* Brady (Fig. 21) and *C. tenuis* Bornemann (Fig. 12) which are at present included in the genus. The typical Cristellaria is marked by the coiled form as the acme of its development (Figs. 18, 19), with a resulting close-coiled form throughout its life history beginning with the third nepionic chamber.

As with Nodosaria, a formula may be made to represent the stages in development. In Cristellaria it is the third chamber which is the determinative one, and the formula for the close-coiled form (Fig. 18) would be, Cristellaria = L + N + C. The absence of repetition of any letter in the formula indicates progressive development as a coiled form, as no senescence is seen in the form or arrangement of the chambers in typical species which are close coiled in the adult.

Cristellaria as at present recognized contains species showing excellent differences in the degree of acceleration of development. In such species as *C. articulata* Reuss (Fig. 9), the close-coiled character after being taken on, extends throughout the succeeding life history. In others, as *C. siddalliana* Brady (Fig. 10), the main part of the shell is close-coiled but towards the end of its growth there is an uncoiling seen in the last three chambers of this specimen. This is brought about by the failure of chamber 21 to extend back to the preceding coil and the continued shrinking away of the next-formed chambers, 22 and 23.

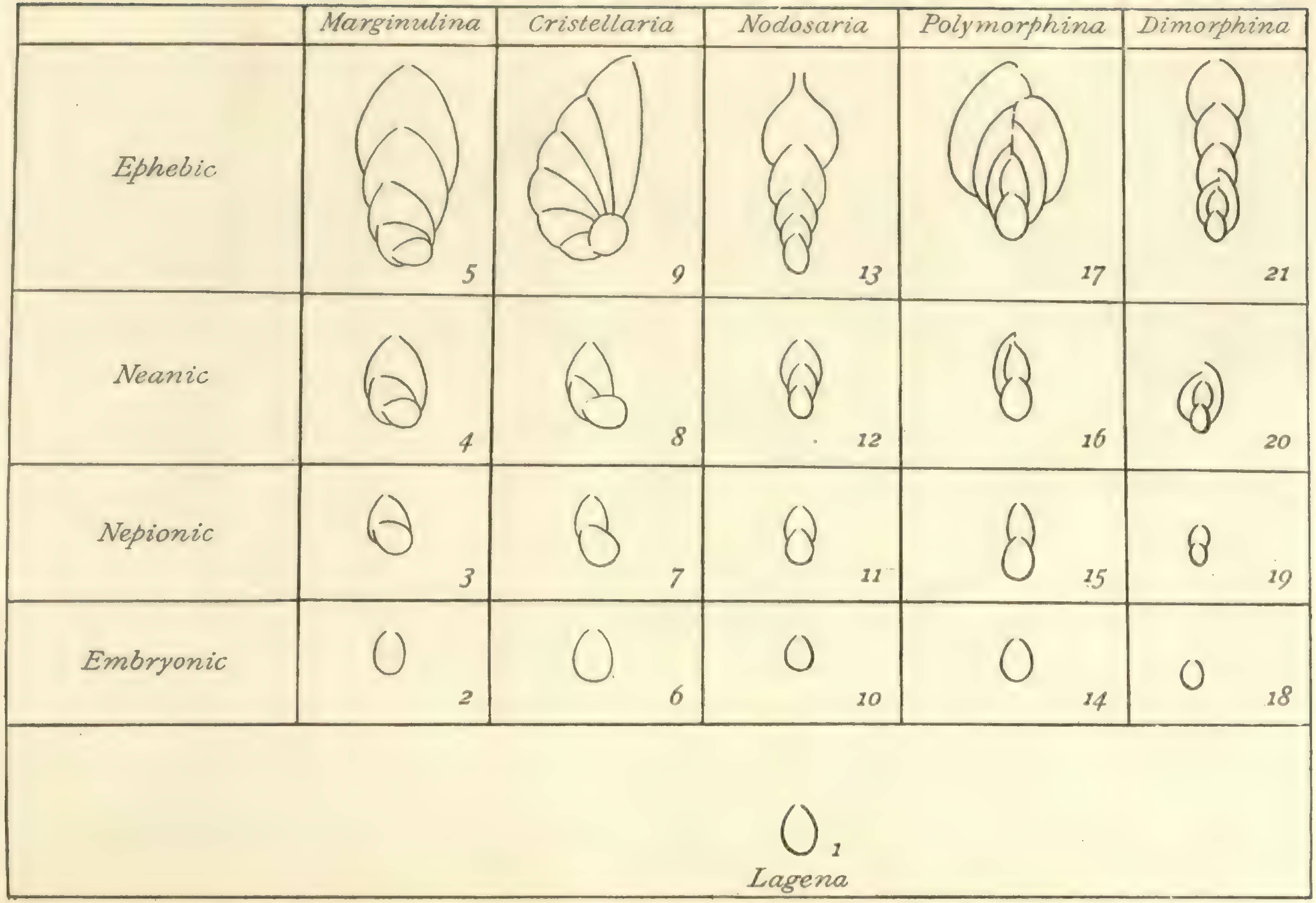
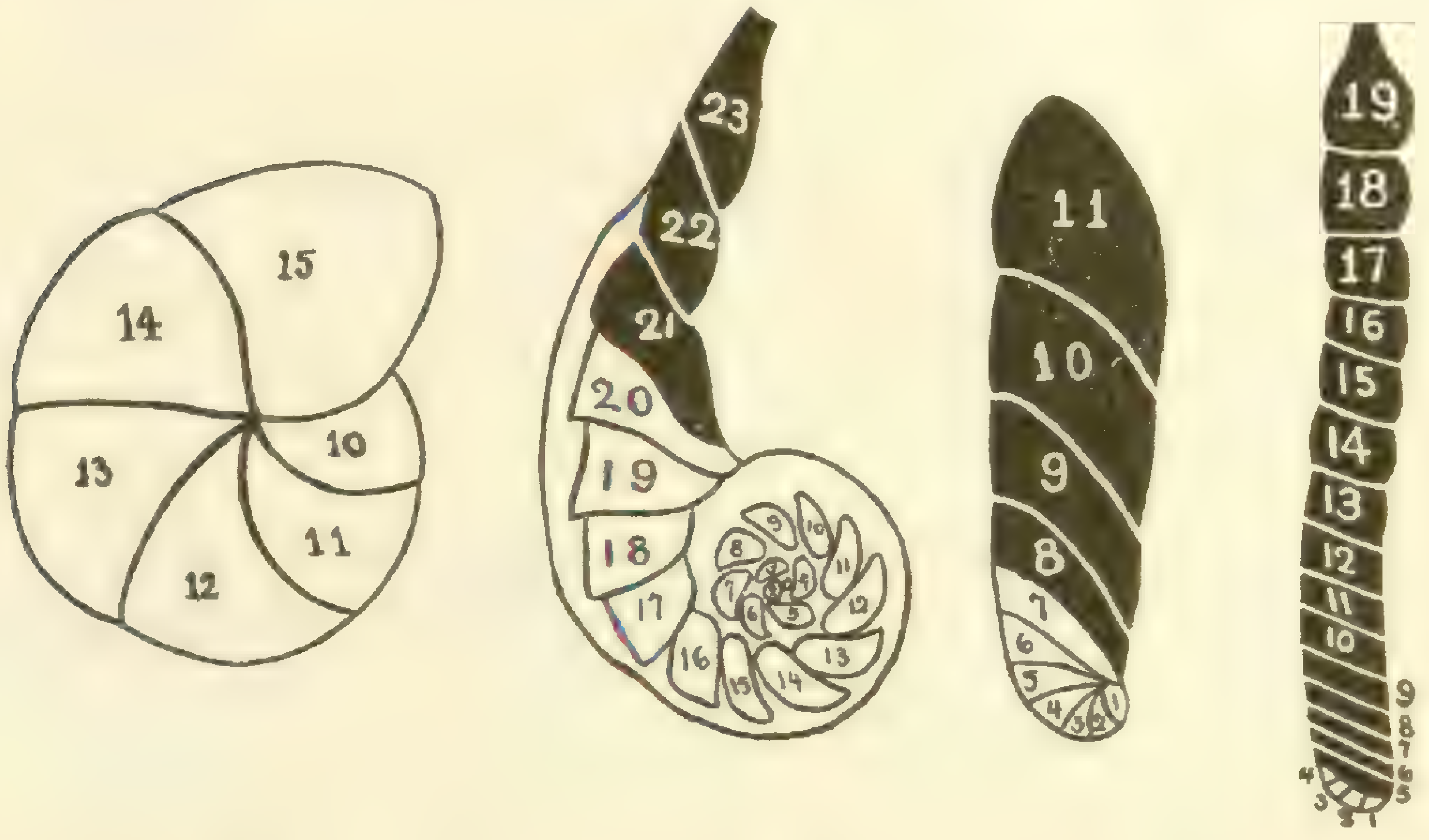

Marginulina
Cristellaria
Nodosaria
Polymorphina
Dimorphina
Ephebic
5
9
13
17
21
Neanic
4
8
12
16
20
Nepionic
3
7
11
15
19
Embryonic
2
6
10
14
18
1
Lagena

PLATE 1.

The figures given show the ontogeny of representative genera of Lagenidæ, arranged to show comparative stages in development. 1, Lagena, the primitive radical; 2-5, stages in development of Marginulina; 6-9, Cristellaria; 10-13, Nodosaria; 14-17, Polymorphina; 18-21, Dimorphina; the embryonic stage, the proloculum, is represented in the lower row and may be compared to Lagena. The nepionic, representing the first two chambers in the next row above, may be compared to Nodosaria. In the neanic shown in the third row the true generic characters are definitely taken on at least as regards progressive characters.

In uncoiling as is shown in Fig. 2, there is a decided change in the angle of curvature from an acute angle gradually to an obtuse one. This seems to be the rule in the stages by which a straight growth is produced from a coiled one as is shown again in Figs. 11 and 12. In *C. schlœnbachi* Reuss (Fig. 11), the uncoiled character is early taken on until on an average only the first six to eight chambers are coiled, while the succeeding chambers which constitute the major part of the whole growth, are



9 10 11 12

FIGS 9–12.— Four species of Cristellaria, showing different degrees in the acceleration of the character of uncoiling. Blackened chambers show the extent of the senescent uncoiled portion. Fig. 9, *Cristellaria articulata* Reuss; Fig. 10, *C. siddalliana* Brady; Fig. 11, *C. schlœnbachi* Reuss; Fig. 12, *C. tenuis* Bornemann (Figures adapted from Brady.)

uncoiled. Thus the senescent character of uncoiling in this last species is more accelerated in its development than in *C. siddalliana* as it originates much earlier in the ontogeny or life history of the individual. In such a species as *C. tenuis* Bornemann (Fig. 12), the coiled portion is usually limited to the first four chambers, while the last fifteen or more are uncoiled. Other specimens of this species show fewer chambers than that figured. This species is then, even more accelerated in development, for the senescent character is so accelerated that it includes four fifths of the entire number of chambers. In the complete return to the straight Nodosarian growth, as shown in the last few chambers of this species, there is a return to a right

angle in the angle of curvature if it may be so called. In the entire development from the right-angled condition in the Nodosarian young, there is a change gradually to an acute, then a right, next an obtuse, and finally back to the right angle again. This then represents the mechanics of the uncoiling. The character of uncoiling in these four species of Cristellaria is represented in Figs. 9–12, in which the black chambers represent the portion showing senescent uncoiling. The white portion shows the extent of the coiled development.

Marginulina.— The first three chambers in the specimen of Marginulina figured (Pl. 1, Fig. 4), are exactly comparable to the same chambers of Cristellaria (Pl. 1, Fig. 8). The first chamber is Lagena-like, the addition of the second gives the oblique Nodosarian form, and the third is seen to be truly Cristellarian. The formula thus far would be as in the preceding, L + N + C. The fourth and fifth chambers in this specimen of Marginulina, however, present a new feature; they fail to extend back to the initial one, but strike off at a tangent showing the incipient stage of uncoiling. The chambers as built, continuing in the line or direction initiated by the fourth chamber, form a Nodosarian growth and the adult therefore may be represented by the formula, Marginulina = L + N + C + N. This is shown in Fig. 14 in section, and in Fig. 13 from the exterior.

13

14

FIG. 13.— *Marginulina ensis* Reuss, showing the main portion of the growth uncoiled.
FIG. 14 — Section through median line of *Marginulina glabra* d'Orb.

In certain cases in old age the last-formed chamber is less closely overlapping than the preceding and therefore takes on a form very much like Lagena. In Marginulina, representing this last chamber in the formula we have, Marginulina = L + N + C + N + L. This shows a complete cycle of stages seen in progressive and typical sen-

escent or regressive development. Such forms as that figured and the majority of species usually classed under Marginulina are not intermediate between Nodosaria and Cristellaria as is commonly stated, but are truly senescent species derived from Cristellaria and resulting from acceleration of development and the shoving back of the Cristellarian character to the early stages in development.

Polymorphina.—The proloculum or initial chamber in Polymorphina as shown in Fig. 15, is here also simple, like Lagena, as in the previous genera. The second chamber (Pl. 1, Fig. 15) is added in the same manner as in Nodosaria and in the second stage in all its visible characters Polymorphina apparently belongs to that genus. The addition of the third chamber (Pl. 1, Fig. 16) initiates a new character in the line of development. It continues back over the preceding one to the proloculum as in Cristellaria but is added in a different manner being so placed that the aperture faces the line of the median axis. This generic character may be represented by P and the formula for the genus may be expressed as follows: Polymorphina = L + N + P. The fourth chamber also extends back to the initial chamber (Pl. 1, Fig. 17) but is added on the opposite side from the third with its aperture facing and occluding that of the third, and this character continues throughout further growth to the adult. This is then a progressive form and after its Nodosarian second stage, starts a new line of development which at once places it in a different group from Cristellaria and Marginulina.

FIG. 15.—Section through median plane of *Polymorphina compressa* d'Orb. After Flint.

Dimorphina.—In this genus the early stages up to the fourth chamber (Pl. 1, Fig. 20,) are exactly as in Polymorphina and may be represented by the same formula, L + N + P. If the animal had died at this stage it would be described as Polymorphina. After this stage, however, a quite different mode of growth is assumed. Beginning with the fifth chamber, suc-

ceeding chambers are arranged in a linear series and are therefore Nodosarian in character. The formula for the adult would be, Dimorphina = L + N + P + N. The last chamber is often more or less free and like Lagena. The formula for the completed growth including this gerontic character will then be, Dimorphina = L + N + P + N + L. Dimorphina is therefore a senescent genus having as its basis the three progressive characters of Polymorphina and in senescence has, by retracing in inverse order, attained in the last chamber to a condition comparable to that seen in the proloculum, or in other words to Lagena. Having completed the cycle, such forms evidently have attained completion along certain lines of development and no new forms can originate from this senescent type except in regard to minor changes in character of ornamentation which are recognized as specific and not generic in value.

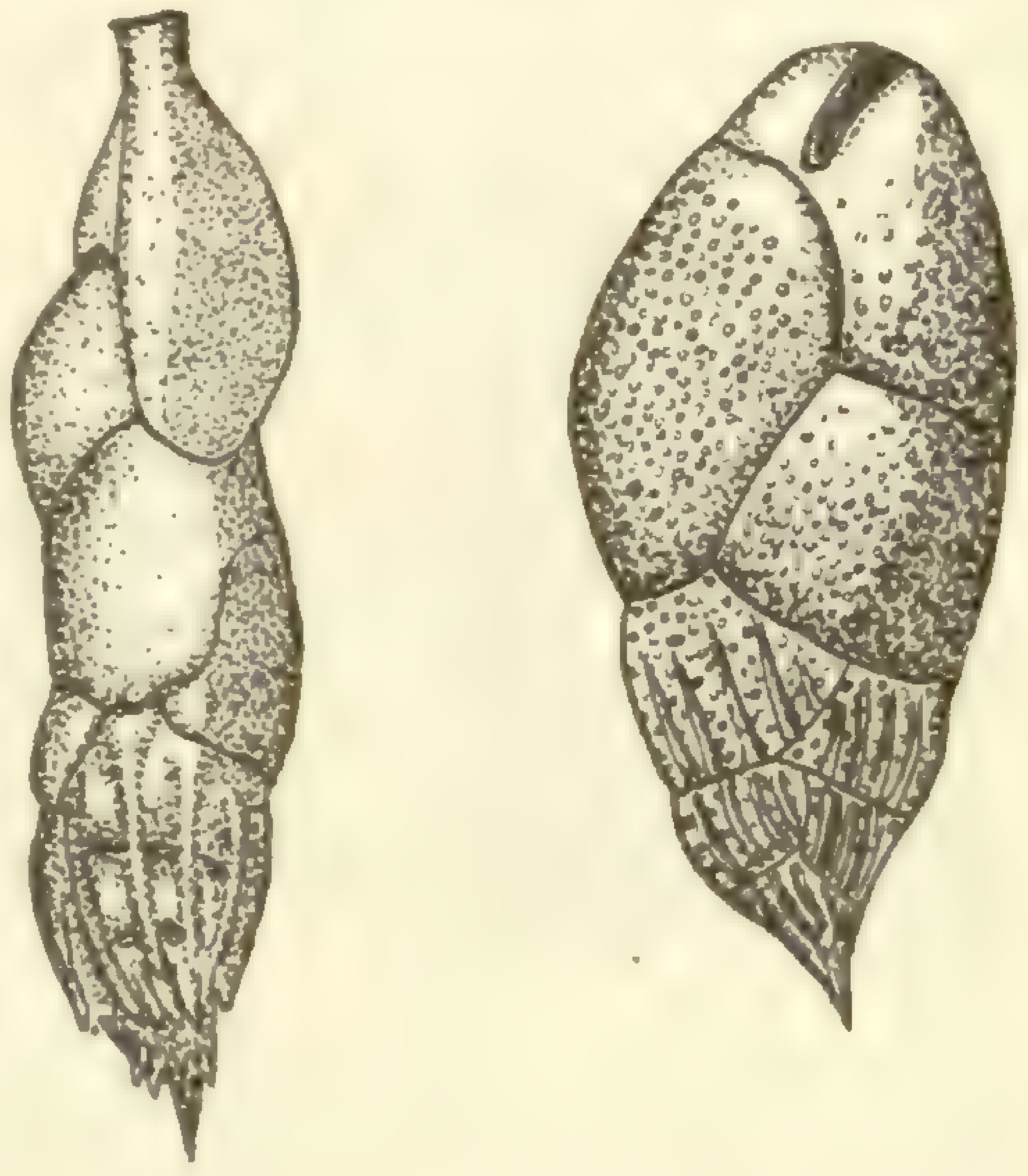
Senescent Characters.

Characters showing typical senescence are frequent among the Foraminifera and illustrate in simple terms conditions similar to those found in many other groups of the animal kingdom. The simplest of these senescent characters is the loss of ornamentation. The ornamentation of this group is shown mainly by elevated ridges, by tubercles, or by spines. Examples of the loss of these will be given. As found by Hyatt in Cephalopoda, the uncoiling of forms, which in their early development were close-coiled, is a decided feature of senescence. Such cases are seen in their simplest terms among the Foraminifera. As shown by Beecher, one of the characters apt to appear in the decline of a group is a peculiar spinose or extravagant growth, "wild" growth, as it is sometimes called in the Foraminifera. Certain senescent genera of Foraminifera show this character exceptionally well. One of the surest indications of senescence is a return to the simpler conditions seen in the young of the same individual and in the adults of more primitive forms. Excellent and at the same time very simple cases of this are seen in Dimorphina and in Dentalinopsis. The Foraminifera as uni-

cellular organisms seem to present the simplest conditions and examples for the expression of the various laws of development that can be found anywhere in the animal kingdom.

Loss of Ornamentation.

Ridges. — In a specimen of *Uvigerina angulosa* Williamson, var. *spinipes* Brady (Fig. 16), the early chambers have definite raised costæ or ridges running generally parallel to the axis of the growth of the shell. In later growth this character becomes less pronounced and in the last five chambers which by measurement represent more than half of the growth, is entirely wanting, and the chambers are perfectly smooth. Although not included in this family, *Bulimina subornata* Brady is figured here for comparison. It shows in much the same manner (Fig. 17) the costate early growth and the gradual disappearance and final loss of costation in the old age of the individual.



16 17

Fig. 16.— *Uvigerina angulosa* Williamson, var. *spinipes* Brady, showing loss of ornamentation in senescence.

Fig. 17.— *Bulimina subornata* Brady, showing similar senescence. (After Brady.)

Tubercles.— In *Cristellaria echinata* d'Orb. (Fig. 18), the early growth is marked by rows of bead-like tubercles over the sutures, while the intermediate space is covered with hemispherical granules. In later growth these scattered granules are limited to the peripheral portion and on the last two chambers are entirely wanting, so that the surface of these chambers is smooth. The rows of bead-like tubercles also disappear in old age and pass into a smooth ridge. Similar conditions are found in various groups of the Mollusca, especially in certain of the fossil Trigonias. In such forms the costæ break up into knobs and bosses in development, and later in the old age of

the individual again resume a costate condition by the merging together of the tubercles.

Spines. — In the preceding species, *C. echinata* d'Orb. (Fig. 18), the loss of spines is a very evident character in senescence.

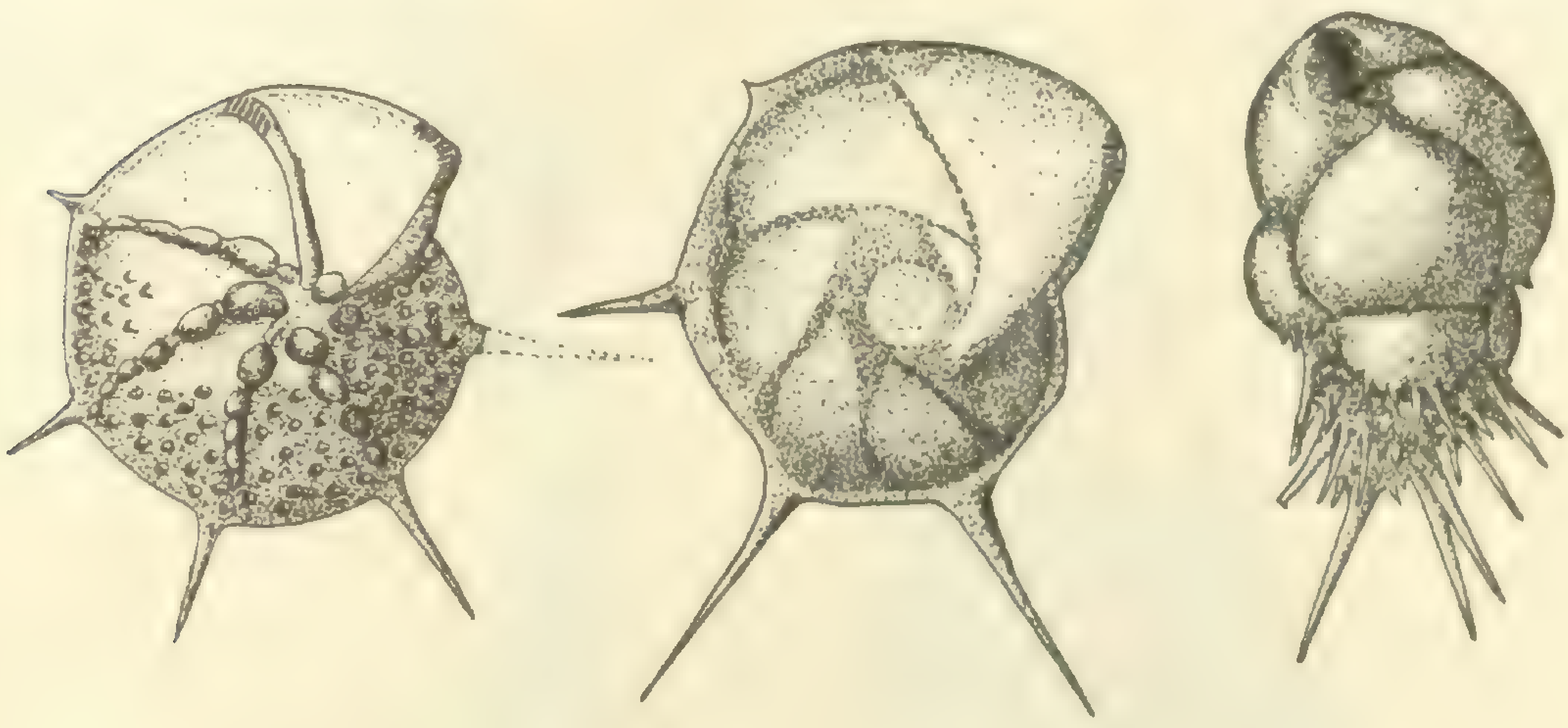


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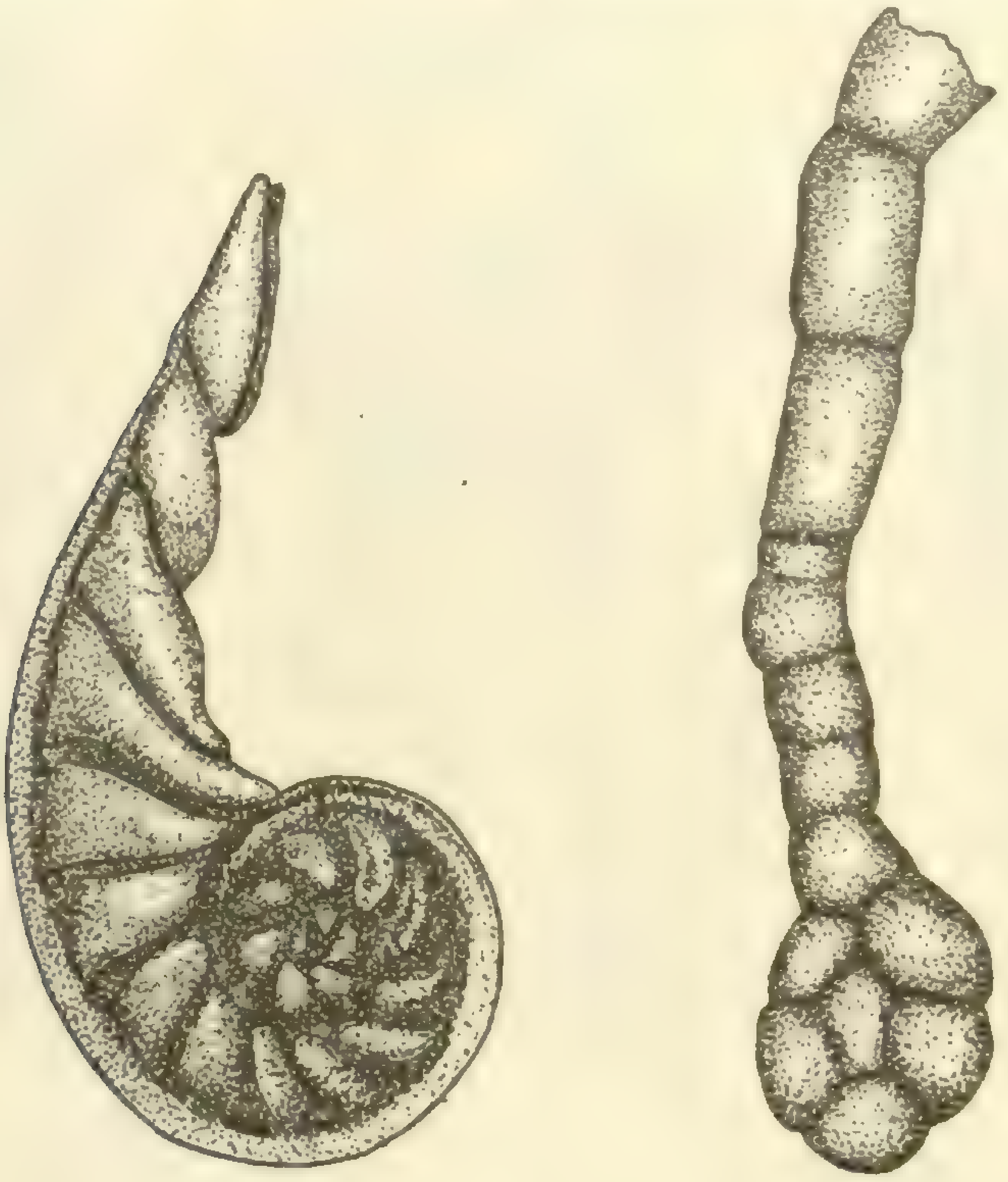
FIG. 18 — *Cristellaria echinata* d'Orb., showing loss of ornamentation in senescence.
FIG. 19.— *C. calcar* Linn., showing loss of spines.
FIG. 20 — *Bulimina aculeata* d'Orb., showing similar loss of spines (After Brady.)

In the median portion of growth the peripheral spines at the sutures are long, at least equalling the length of the chamber on the peripheral margin. The third from the last is shorter and the last two spines decrease progressively in size, the last one being very short, while at the last suture no spine at all is developed. Much the same condition of affairs in regard to the reduction and loss of spines is seen in *C. calcar* Linn. (Fig. 19), in which, however, the spines do not coincide with the suture lines. Another excellent example, although not in the same family, is that presented by *Bulimina aculeata* d'Orb. (Fig. 20). Here the early growth is marked by well developed spines. As growth progresses, the spines of successively added chambers are not so greatly developed. Toward the later growth, traces of them are seen in the very reduced spines at the posterior angles and on the last-formed chambers they are lacking, and the chambers are perfectly smooth.

These examples of loss of ornamentation as a character in senescence are exactly comparable to cases already worked out

by others in the Cephalopoda, Pelecypoda, Gastropoda, and Brachiopoda and they are seen in still other groups.

Uncoiling.— *Cristellaria siddalliana* Brady (Fig. 21) shows an excellent case of uncoiling not carried to an extreme. The



21 22

Fig. 21.— *Cristellaria siddalliana* Brady, showing uncoiling in last few chambers.
Fig. 22.— *Trochammina lituiformis* Brady, showing uncoiling carried to an extreme.

early chambers are close-coiled and this feature continues until the last few chambers. Here there is a distinct change and an uncoiled form is produced as shown in the figure. This uncoiling is only seen in well advanced specimens that show old age characters. Other examples of uncoiling in Cristellaria have already been given (Figs. 11, 12). Although outside of this family, *Trochammina lituiformis* Brady is figured (Fig. 22) to show the character of uncoiling carried to an extreme. The early chambers make a little more than a single volution, while the succeeding growth is uncoiled. In old age specimens, this character may be carried to a greater extent than is shown in Fig. 22. In this species in contrast to the preceding, the majority of the chambers form the uncoiled portion of the shell. Such examples are exactly comparable to Baculites or Lituites

among the Cephalopoda or to Vermetus or Magilus among the Gastropoda.

Spinose or "Wild" Growths.— In Polymorphina and Sagrina of this family the last chambers are often peculiarly different from the preceding ones. In *Polymorphina orbignyii*, as figured by Brady, Parker, and Jones (*Trans. Linn. Soc. London*, vol. 27, p. 244, pl. 42, fig. 38c) the last chamber is marked by a peculiar fistulose growth, greatly differing from the preceding regular chambers of the species (Fig. 23). Such growths are

23

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Fig. 23.— *Polymorphina orbignyii* with peculiar fistulose growth in senescence.
Fig. 24.— *Uvigerina aculeata* d'Orb. with "wild" growth. (After Brady.)

not infrequent in various other genera. Corresponding "wild" growths appear in certain species of Cristellaria. In *Uvigerina aculeata* d'Orb. (Fig. 24) similar characters appear. This species in its younger development has simple longitudinal costæ. Later, however, there is a thickening by addition from the outside and the last chamber is covered with a decidedly spinose development totally different from the previous ornamentation. This spinosity may continue, extending progressively posteriorly until it envelops the whole shell, covers the preceding chambers, and hides all traces of the typical earlier ornamentation. These growths seem to be best regarded as senescent charac-

ters. Such a decided change in method of growth, with an increase in the thickness of the shell without corresponding increase in the number of chambers, may be compared in a general way to the building up of tissue in the old age of Brachiopoda and Mollusca where there is no increase in size of the living chamber but frequently a decrease. It may be more closely compared to similar conditions which appear in the Gastropoda for example in the several Eocene species of Calyptraphorus where by reflection of the mantle in later growth a callous develops which hides the previous sculpturing.

Return to Simpler Conditions.

Dimorphina.— In this genus, the development of which has already been noted, there is a return to a straight uniserial growth in the later chambers. This was expressed by the formula L+N+P+N+L. It is a true return to the Nodosarian and Lagena characters seen in the progressive development of the first two chambers. The biserial Polymorphine character in Dimorphina is accelerated so that it may appear in but two chambers including the third and fourth and a return to the uniserial condition is then taken on in the fifth. This return to the simpler Nodosarian condition, seen in the young of the same individual and again as the acme of development in an ancestral type, Nodosaria, can be regarded only as a truly senescent character and the genus Dimorphina a senescent one derived from Polymorphina.

Fig. 25.— *Dentalinopsis subtriquetra* Reuss, showing return to circular cross section in the last-formed chamber. (After Reuss.)

Dentalinopsis.— In this genus (Fig. 25), the early chambers are uniserial like those of Nodosaria. At first they are circular in cross section but soon become triangular or polygonal. At this point the species which have this character as their highest development are classed under the genus Rhabdogonium which is characterized by angular section in the adult. The formula for Rhabdogonium would be L + N + R.

Senescent forms have been found among the fossils and to such forms Reuss has applied the generic name Dentalinopsis. In species of this genus the later growth instead of being triangular reverts to its earlier circular cross section and becomes truly Nodosarian. Reuss noted the generic value of this senescent character, although his genus has not always been recognized by later writers. The last-formed chamber may be more free and distinctly Lagena-like, thus completing the reversion in senescence. The formula for a specimen which has the Lagena-like last chamber would be L + N + R + N + L, showing its definite regressive senescence.

STUDIES ON THE PLANT CELL.—VII.

BRADLEY MOORE DAVIS.

SECTION V. CELL ACTIVITIES AT CRITICAL PERIODS OF ONTOGENY IN PLANTS (*Continued*).

5. APOGAMY.

APOGAMY is the suppression of the sexual act and the development of a succeeding generation asexually. The term was first proposed by De Bary in 1878, following Farlow's ('74) discovery of the phenomenon in *Pteris cretica*. The succeeding generation may arise in one of two ways: (1) by the development of an unfertilized egg or gamete which is termed parthenogenesis, or (2) by some form of vegetative outgrowth from the sexual plant, a process which has been called vegetative apogamy. We shall not attempt to give a detailed account of apogamy in the plant kingdom but will confine ourselves chiefly to the consideration of a few detailed studies of recent months which have taken up the cell problems concerned. The cell problems naturally treat of the processes which may be substituted for the sexual act in ontogeny and the fundamental problems of the behavior of the chromosomes under these conditions.

Parthenogenesis has been known for many years among the thallophytes which furnish illustrations in a variety of groups. In the algæ we have the well known examples of *Chara crinita*, Cutlaria, Dictyota, some species of Spirogyra and Zygnema, and a number of types in the lower Chlorophyceæ and Phæophyceæ whose motile gametes will germinate like zoöspores should they fail to conjugate with one another. The recent studies of Williams (:04b) on Dictyota give the only observations which have been made on nuclear activities during the parthenogenetic development of eggs in any algal form and will be considered presently. The fungi furnish beautiful illustrations of partheno-

genesis in the Saprolegniales. Trow (:04) believes that some of these forms are sexual but there can be little doubt that the group as a whole is generally apogamous. There is probably much apogamy in the Ascomycetes and an almost entire suppression of sexual organs in the Basidiomycetes but no clear instance of parthenogenesis (*i. e.*, a development from a cell whose morphology is unquestionably that of an egg) is known in either of these groups.

Parthenogenesis is not known in the bryophytes and pteridophytes excepting for Marsilia (Shaw, '97; Nathansohn, :00). Although there is much apogamy in the pteridophytes, especially in the leptosporangiate Filicales, the new generation generally develops as a bud-like outgrowth on the prothallus (vegetative apogamy). There have been no nuclear studies on the parthenogenetic Marsilia but an interesting preliminary account has appeared announcing nuclear fusions in the apogamous development of Nephrodium (Farmer, Moore, and Digby, :03).

Parthenogenesis is now known in the spermatophytes for *Antennaria alpina* (Juel, '98, :00), several species of Alchemilla (Murbeck, :01a, :01b, :02; Strasburger, :04c), *Thalictrum purpurascens* (Overton, :02, :04), Gnetum (Lotsy, :03), a number of forms of Taraxacum (Raunkiaer, :03; Murbeck, :04), several species of Hieracium (Ostenfeld, :04a, :04b; Murbeck, :04), *Wikstrœmia indica* (Winkler, :05), and is suspected for Ficus Treub, :02) and *Bryonia dioica* (Bitter, :04). A number of cases of polyembryony were formerly considered examples of apogamy but are now known to be developments from the nucellus and consequently vegetative buds of sporophytic origin and entirely independent of gametophytic activities. The best known of these forms are Funkia, Cœlebogyne, Citrus, Opuntia, and *Alchemilla pastoralis*. Vegetative apogamy is illustrated in the development of embryos from antipodal cells as in *Allium odorum* (Tretjakow, '95; Hegelmaier, '97) or from the cells of the endosperm as in Belanophora (Treub, '98; Lotsy, '99). Synergids have been reported to form embryos in a number of forms but many of these have proved to be cases in which the synergid is fertilized by a sperm nucleus and not examples of apogamy. However, synergids are known to develop embryos apogamously

(or parthenogenetically if the antipodal be considered the homologue of an egg) in *Alchemilla sericata* (Murbeck, :02). A summary of the various types of vegetative apogamy, parthenogenesis, and sporophytic (nucellar) budding, supplementing a list of Ernst (:01) is given by Coulter and Chamberlain (:03, p. 221).

We will now take up the few investigations which consider the cytological details of parthenogenesis. That of Williams (:04b) on Dictyota is the only one treating of a lower type. It seems probable that parthenogenesis in Dictyota is in no sense normal and would not lead to mature plants, since the germination of unfertilized eggs in the cultures of Williams presented many irregularities. The spindles instead of being formed from asters with centrosomes are intranuclear in origin, multipolar, and very irregular in their form. As a result the 16 chromosomes become scattered and a cluster of daughter nuclei is formed containing varying numbers of chromosomes, sometimes one and sometimes several. It is clear in Dictyota that the fertilization of the egg results in the development of an aster with a centrosome which exerts a directive influence in mitosis preventing a scattering of the 32 chromosomes and conducting the mitosis in a normal fashion. Williams does not believe that the centrosome is introduced as an organized structure into the egg by the sperm but that it is formed *de novo* as a result of the increased metabolic activities present in the fusion nucleus as compared with that of the unfertilized egg.

There have been several important studies on parthenogenesis in the spermatophytes. Some of these papers while establishing the facts of parthenogenesis in various forms, give no details of nuclear history or behavior of the chromosomes. But the studies of Juel (:00), Overton (:04), and Strasburger (:04), present some very interesting data on the cytological features of parthenogenesis in *Antennaria alpina*, *Thalictrum purpurascens*, and several species of Alchemilla.

Several recent papers indicate that parthenogenesis may prove to be general in certain genera or even characteristic of large groups and therefore a far more widespread phenomenon than has been supposed. Raunkiaer (:03) (abstract in English in *Bot. Centralb.*, vol. 93, p. 81, 1903) proved by cutting off the

tops of young flowers that several species of Taraxacum produced normal seeds apogamously and concluded that the embryo must develop parthenogenetically since Schwere, in 1896, traced its origin from the egg. Ostenfeld (:04a, :04b) from failure to find pollen on the stigma of Hieracium and failure to make it germinate in a number of solutions, was led to try similar experiments to those of Raunkiaer in cutting off the anthers and stigmas of flowers. He found that a large number of species of Hieracium were able to set seed apogamously and he believed parthenogenetically but histological investigations were not made to establish the last point. The experiments of Raunkiaer and Ostenfeld are interesting as showing how a form by virtue of its parthenogenetic habits might become segregated and quite removed from the probability of hybridization. Murbeck (:04) in a short paper announced that the embryos in Taraxacum and Hieracium, developing from flowers whose stamens were cut out (as in the experiments of Raunkiaer and Ostenfeld) actually do develop from the egg cell and are therefore parthenogenetic. Murbeck also failed to find pollen tubes in the ovules where pollen had been applied to the stigma. Winkler (:04) reports that *Wikstrœmia indica* matures very little perfect pollen and produces its seeds apogamously, as proved by experiment. The embryos are stated to develop parthenogenetically from the egg but no details are given in this preliminary paper of the chromosome history. This group of contributions while very interesting, presents no data on the fundamental problems in a cytological explanation of parthenogenesis.

Murbeck (:01a) concluded for Alchemilla that true tetrads were formed previous to the differentiation of the embryo-sac but nevertheless found evidence that there were no reduction phenomena so that the nuclei within the embryo-sac contain the sporophytic number of chromosomes. Murbeck's evidence of tetrad formation was not satisfactory and in the light of recent studies of Strasburger (:04c) cannot be accepted. His view was, however, correct that there is no reduction of the chromosomes in the formation of such embryo-sacs as produced parthenogenetic embryos.

Juel (:00) gives a critical comparison of the development of

the embryo-sac in the parthenogenetic *Antennaria alpina* with *A. dioica* whose ovules are normally fertilized. In *A. dioica* the embryo-sac is one of a group of four cells (tetrad) which are formed through two successive mitoses (heterotypic and homotypic) showing the characteristic features of sporogenesis. A clear stage of synapsis precedes the first mitosis. The type of embryo-sac development in this form is then entirely normal. Not only are tetrads suppressed in the parthenogenetic *Antennaria alpina* but there is no trace of the heterotypic and homotypic mitoses in the embryo-sac. The number of chromosomes is very large (about fifty) and evidently the same as is found in other periods of the life history. There is then no reduction of the chromosomes during the formation of the embryo-sac in the parthenogenetic species and the egg and other nuclei in this structure have consequently the sporophytic number. There is no need of fertilization to bring the egg to a condition when with respect to chromosomes it is prepared to develop a sporophyte embryo. Juel (:04) notes certain peculiarities in the development of the embryo-sac of *Taraxacum officinale*. Tetrad formation is reduced to a single mitosis and this is not heterotypic, since there seems to be no reduction of the chromosomes. Details are not given.

Overton (:04) finds normal reduction phenomena in the pollen mother-cell of *Thalictrum purpurascens* which establishes the number of chromosomes to be 24 for the sporophyte and 12 for the gametophyte generations. These mitoses are thoroughly typical of sporogenesis being preceded by a synapsis stage. The development of the embryo-sac is of two types. In some cases a tetrad of four megaspores is formed from a megaspore mother-cell. The nucleus of this cell passes through a synapsis and the first mitosis is heterotypic showing the reduced number of chromosomes. The lower cell of the tetrad becomes the embryo-sac. But many embryo-sacs pass through a different history. There is no heterotypic mitosis and no reduction of the chromosomes which remain 24 in number. Thus in some ovules the mitoses of sporogenesis are omitted and true tetrads are not formed, with the result that the embryo-sac contains nuclei with the sporophyte number of chromosomes (24) in

place of the gametophyte (12). The details of the nuclear history in these embryo-sacs have not been followed but it is plain that their eggs have the requisite number of chromosomes to develop sporophyte embryos parthenogenetically. The varying proportions of parthenogenetically developed seeds which may be found on plants of *Thalictrum purpurascens* indicate that the suppression of normally developed embryo-sacs is not very firmly established in this form.

We now come to a recent paper of Strasburger (:04c) which is the most important contribution to the subject of parthenogenesis that has yet appeared. Strasburger studied a number of species of Alchemilla from the section Eualchemilla, the group which formed the subject of Murbeck's important discoveries. Most of the forms develop pollen in a normal manner and Strasburger was able to follow reduction phenomena in this process without difficulty. The nucleus of the pollen mother-cell passes through a synapsis followed by a heterotypic mitosis in which the structure of the chromosomes as bivalent elements is apparent. The bivalent chromosomes are in the reduced (gametophytic) number. Similarly Strasburger found that some species (*e. g.*, *Alchemilla pentaphylla*, *gelida*, and *grossidens*) formed embryo-sacs in a normal manner with the presence of a tetrad and a characteristic reduction division (heterotypic). But the development of the embryo-sac in apogamous species (*e. g.*, *Alchemilla speciosa*, *splendens*, and *fallax*) cuts out the two mitoses of sporogenesis and no tetrads are formed. The nucleus of the megaspore mother-cell emerges from synapsis with the sporophyte number of chromosomes and the first division which follows is a typical mitosis and not heterotypic. The embryo-sac then comes to contain a group of nuclei with the sporophytic number of chromosomes in place of the gametophytic and a parthenogenetic development of the egg takes place. Strasburger regards the parthenogenetic tendencies of Eualchemilla as associated with excessive mutations among these forms through which sexual processes are becoming displaced by apogamous methods of reproduction.

This clear evidence that the cause of parthenogenesis in Antennaria, Thalictrum, and Alchemilla lies in the suppression

of chromosome reduction during the formation of the embryo-sac seems to offer an explanation of other examples of apogamy presented by the embryo-sac. Thus apogamous developments of embryos from synergids as in *Alchemilla sericata* (Murbeck, :02) or from antipodals as in *Allium odorum* will not seem strange if reduction processes are suppressed in the production of an embryo-sac and its nuclei retain the sporophyte number of chromosomes. Such nuclei have in them the same potentialities of development as do those of the nucellus whose cells form embryos vegetatively and entirely independent of gametophytic activities in a number of forms (*e. g.*, Funkia, Cœlebogyne, Citrus, Opuntia, *Alchemilla pastoralis*, etc.). This type of apogamy from a gametophyte which retains the sporophyte number of chromosomes may be found to hold a very close relation to apospory for there is the same reduction or omission of the processes of sporogenesis as is found in that phenomenon. However, since we know nothing of the cytological events of apospory it is unwise at present to follow the speculation further.

The peculiarities of parthenogenesis in the spermatophytes do not seem so remarkable since the discoveries recorded above. It is not strange that an egg should form an embryo without fertilization when its nucleus contains the sporophyte number of chromosomes. The most remarkable feature in this suppression of reduction phenomena in Antennaria, Thalictrum, and Alchemilla is the possibility of developing an embryo-sac with nuclei in the number and arrangement typical of the female gametophyte and yet with the sporophyte count of chromosomes. The embryo-sacs with their contents have clearly the morphology of female gametophytes and must be so considered in spite of the fact that their nuclei contain twice as many chromosomes as usual. It is clear that the potentialities of sporophyte and gametophyte involve other factors besides those of the chromosome count. This is a very important conclusion because we have been accustomed to lay great weight on the number of chromosomes as the cause of sporophytic and gametophytic developments respectively. We must recognize the presence of other factors determining alternation of generations besides the chromosomes.

There are two types of parthenogenesis in plants: (1) that in the thallophytes where there is no sporophytic generation, and (2) that in higher forms when the life history is complicated by an alternation of generation. We know nothing of the cytological conditions in the first group including such types as *Chara crinita*, Cutlaria, some species of Spirogyra and Zygnema and numbers of the lower Chlorophyceæ and Phæophyceæ whose motile gametes will germinate like zoöspores should they fail to conjugate with one another. But since there is no reason to suppose that there are reduction phenomena at gametogenesis, the unfertilized gamete is fully prepared with respect to the number of chromosomes to continue the parent stock. Dictyota must be excluded from this list since the parthenogenetic developments here are abortive. In the second group parthenogenesis is likely to prove to be the result of a suppression of reduction processes during sporogenesis by which a gametophyte generation retains the sporophyte number of chromosomes and in consequence is prepared to dispense with sexual processes in the development of a new sporophyte. Parthenogenetic development in animals seems to be similar in its essential cytological features to parthenogenesis and apogamy in plants. There may be a suppression of reduction processes somewhat comparable to that discussed above, which takes place, however, at the time of gametogenesis, whereby the egg nucleus retains the number of chromosomes characteristic of the parent. Or, through a fusion with the nucleus of the second polar body the egg nucleus is brought back to the normal condition with respect to the number of chromosomes of the parent stock. We cannot, however, consider in detail the forms of parthenogenesis in animals. They have been recently treated by Blackman (:04b) in comparison with conditions in plants.

Apogamous developments which involve wholly or in part other elements than gamete cells and nuclei are likely to be established in a number of groups of the thallophytes. The author has long believed that the cystocarps of some of the Rhodophyceæ develop apogamously, basing his conclusions on certain general peculiarities of the group and more particularly on a study of Ptilota (Davis, '96). Three species of this genus

were investigated and no developments from the carpogonia were found, but the cystocarp in all cases arose from a cell near the base of the group of procarps. These conditions together with the rarity of male plants on the American coasts (none have ever been reported) give strong evidence for apogamy in Ptilota. There are a number of genera of the Rhodophyceæ where similar conditions seem to obtain and which lead one to suspect that apogamy may not be very exceptional. However, the subject has been very little studied.

As is well known, the Ascomycetes furnish numbers of illustrations where ascogonia have not been found or appear in what seem to be reduced conditions and even when accompanied by so called antheridial filaments these latter have not been established as functional. De Bary recognized the possibility of apogamy in the development of the ascocarps of these forms and very little critical study has been given to them since his time. The trend of investigations in this group has been towards the more interesting problems of the establishment of sexuality in a few well known forms (*e. g.*, Gymnoascus, Sphærotheca, Pyronema, Monoascus, and among the lichens and Laboulbeniaceæ.)

It is generally believed that no sexual organs are present in the higher Basidiomycetes (Autobasidiomycetes). But the recent studies of Blackman (:04a) in the Uredinales, taken in relation to the well known nuclear fusions in the basidium, preceded by a mycelium containing paired (conjugate) nuclei, make it seem very probable that former sexual processes in the Basidiomycetes have been replaced by a remarkable type of apogamous development of a sporophyte generation. Blackman has traced the origin of the paired nuclei in the Uredinales (Phragmidium) to a structure preceding the æcidium, a structure which seems to be the remains of a female sexual organ. We will take up this investigation presently There is then much reason for believing that a sporophyte generation in the Basidiomycetes arises apogamously in the creation of the paired nuclei and terminates with their fusion within the teleutospore or basidium.

The leptosporangiate ferns have furnished some of the best

illustrations of apogamy. Since Farlow's discovery in 1874 of an asexual sporophytic growth from the prothallus of *Pteris cretica* the list of apogamous pteridophytes has steadily increased until now the phenomenon is known in perhaps 25 forms. Farlow's investigation was followed by an extended study of De Bary ('78) on a large number of forms in the Polypodiaceæ and resulted in the establishment of similar sporophytic outgrowths in *Aspidium falcatum* and *Aspidium filix-mas cristatum.* De Bary proposed the term *apogamy* ('78, p. 479) for the general phenomenon and distinguished two forms, *apandry* the suppression of the male sexual organs which results in a parthenogenetic development of the egg, and *apogyny* for the suppression of the female. Sadebeck in the following year reported apogamy in Todea one of the Osmundaceæ (Schenk's *Handbuch der Botanik*, vol. 1, p. 231, 1879) thus extending the phenomenon to another family. And later apogamy was found in *Trichomanes alatum* one of the Hymenophyllaceæ (Bower, '88) and in *Selaginella rupestris* (Lyon, ':04, p. 287).

The most important recent contribution on apogamy in ferns is by Lang ('98, abstract in *Annals of Bot.*, vol. 12, p. 251). This paper presents an able discussion of the phenomenon in its relation to alternation of generations and adds the very interesting discovery of sporangia borne directly on prothalli that were grown from spores. These sporangia were found in clusters on a thickened lobe or process from the prothalli of *Scolopendrium vulgare ramulosissimum* and *Nephrodium dilatum cristatum gracile.* The sporangia were perfectly normal in structure and they matured spores. It is probable that the process is itself sporophytic in character, *i. e.*, made up of cells with double the number of chromosomes of the true gametophytic portion of the prothallus, but cytological details are not known. Lang's study of the apogamous development of sporophytic buds on several forms of the Polypodiaceæ is the most detailed work on apogamy in the pteridophytes yet published. The apogamous growths appeared as the result of cultures which were watered entirely from below and exposed to direct sunlight, important departures from normal conditions surrounding fern prothalli. In all cases the prothalli developed normal

embryos when the conditions permitted of fertilization. We shall refer to some general considerations of Lang in our summary and conclusions on apogamy.

The spermatophytes present some exceedingly interesting examples of apogamous developments of embryos from nuclei within the embryo-sac other than the egg, as from antipodals (*Allium odorum*, Tretjakow, '95 ; Hegelmaier, '97) or synergids (*Alchemilla sericata*, Murbeck, : 02) or nuclei in the endosperm (Belanophora, Treub, '98 ; Lotsy, '99) but in these cases the sporophyte number of chromosomes is apparently present through a suppression of the reduction phenomenon of sporogenesis in the development of the embryo-sac.

We will now consider two studies which describe nuclear fusions preliminary to the appearance of apogamy (Blackman, : 04a ; Farmer, Moore, and Digby, : 03).

Blackman's (: 04a) observations on Phragmidium have cleared up to a great degree our understanding of the life history of the Uredinales. The chains of æcidiospores have been found to arise serially from "fertile cells" which form a group at the spot where an æcidium is to be developed. Each fertile cell has above it a sterile cell which, however, breaks down. The sterile and the "fertile cell" together may represent a female sexual organ, the sterile cell perhaps standing for the remains of a receptive structure similar to a trichogyne. The spermogonium consists of a large mass of antheridial filaments that abjoint sperms which are no longer functional. It is of course uncertain whether the "fertile cells" are morphologically the original female gametes since they may readily be other cells drawn into the process of apogamy. The "fertile cell" is stimulated to activity by the entrance of a second nucleus either from an adjacent hypha or from the cell below. The second nucleus does not fuse with the original nucleus in the "fertile cell" but the two come to lie close together as a paired or conjugate nucleus. The two nuclei of the pair divide simultaneously (conjugate mitosis) throughout a long series of nuclear divisions, beginning with the formation of æcidiospores and through the vegetative history which follows up to the production of the teleutospores where the members of the last pairs unite to form

the single fusion nuclei within these reproductive cells. There is much evidence that the period in the life history characterized by the presence of paired nuclei represents a sporophyte phase.

Blackman (:04a, p. 353) regards the process by which the second nucleus enters the "fertile cell," resulting in the conjugate nuclei, as a reduced form of ordinary fertilization. I have already pointed out in Section IV, "Asexual Cell Unions and Nuclear Fusions," what seem to me to be serious objections to the use of the term fertilization when it is clear that the second nucleus in the pair is morphologically not a gamete nucleus, and the subject was also taken up in the account of fertilization in the present section. Whatever may be the physiological interpretation of this remarkable phenomenon it seems to me clearly a substitute process for a former sexual condition and involves other elements than the original gametes and as such is a typical illustration of apogamy.

It seems probable that further studies in the Basidiomycetes will determine a similar origin for the paired nuclei preceding the basidium to that of Phragmidium but without any trace of former sexual organs at least in the higher groups. And these conditions must signify the complete disappearance of structures representing sexual organs and the substitution of an apogamous development of the sporophyte generation for the sexual act. In this connection the interesting nuclear fusions in the ascus are of great interest for they may hold relations to degenerate sexual conditions in the Ascomycetes.

Farmer, Moore, and Digby (:03) have reported some remarkable nuclear fusions preceding the apogamous development of the sporophytes of Nephrodium, which have many points of resemblance to the apogamous phenomena in the Uredinales just described. These authors find that cells of the prothallus from which the sporophytic outgrowths arise, become binucleate through the migration of nuclei from neighboring cells. The two nuclei may remain separate for some time or they may fuse at once. They regard the whole process "as a kind of irregular fertilization" by which the outgrowth destined to form the sporophyte becomes supplied with nuclei containing the double number of chromosomes. It seems to me unfortunate to asso-

ciate the term fertilization with this phenomenon, whatever may be the physiological significance of the nuclear fusions, because we are not dealing with gametes and there cannot be involved in the process anything of the long phylogenetic history of sexual differentiation in the group. We considered these matters in some detail in that portion of this section entitled "Fertilization."

With respect to the factors which determine apogamy it must be confessed that we are still in the dark. Lang's ('98) studies on fern prothalli, however, throw some light on the problem. In some twenty forms of the Polypodiaceæ apogamy resulted when the prothalli were kept from direct contact with the water (*i. e.*, were watered from below) and exposed to direct sunlight. When watered from above these same forms developed normal embryos from eggs. It is clear that the suppression of conditions which make fertilization possible (*i. e.*, water over the surface of the prothallus), possibly aided by sunlight which may cause irregularities of growth, induced the development of cylindrical processes from which the apogamous sporophytes arose and which bore sporangia in two forms. It seems hard to draw more precise conclusions from these experiments other than that the normal life history is checked at a critical period (fertilization) and the plant is forced into expressions of vegetative activity. The conclusions of Farmer, Moore, and Digby (:03) offer an explanation of how the developments may take on sporophytic characters through the fusion of nuclei in the tissues and the establishment of a sporophyte number of chromosomes.

Strasburger suggests that apogamy in Alchemilla may be the result of a weakening of sexual power associated with excessive mutative tendencies. This would seem to imply that exceptional vegetative activity, with the appearance of much variation under favoring conditions, may be combined with apogamy. It is of course a well known fact that a high degree of cultivation tends to lessen the fertility of a form unless guarded by careful selection. A weakened sexual fertility due to excessive vegetative activity is likely to be replaced by forms of vegetative reproduction. When the process of sporogenesis becomes so

reduced or modified that the female gametophyte retains the sporophyte number of chromosomes as in the embryo-sac of Alchemilla and Thalictrum the apogamous development of embryos is to be expected.

The discovery of apospory in such variable and perhaps mutating genera as Alchemilla, Taraxacum, and Hieracium suggests quite a new line of research with possibilities of a clearer understanding of the origin of mutations. It is very interesting that these widespread and successful genera should give evidence of such strong apogamous habits for it seems to indicate an evolutionary tendency in the higher plants of great significance. These forms with Thalictrum are representatives of three large, divergent and very successful orders (Ranales, Rosales, and Compositales) and it suggests the probability that apogamy will be found to be widespread in the spermatophytes. Its bearing on the establishment of extreme variations and mutations may be of the utmost significance for it is clear that the suppression of sexuality would remove sports and mutants at once from the swamping effects of cross-fertilization. The sudden appearance of mutants in some groups and their ability to hold true may indeed be found to rest on the establishment of apogamy in the form. This is at least a possibility which must be considered in cytological investigations on mutants and has not yet received attention.

The subject of apogamy touches another topic of importance, namely, the theory of *homologous* generations as contrasted with *antithetic* generations in comparisons of sporophyte with gametophyte. We shall not take up this discussion in detail here. It must have been apparent to the reader that the present treatment of the critical periods in the life history of plants is based on the conviction of the correctness of the latter view which has had the support of Celakovsky, Strasburger, Bower, Vaisey, and Klebs. The theory of *homologous* generations as held by Pringsheim and Scott is admirably discussed by Lang ('98) in connection with his studies on apogamy and also in a briefer note (*Annals of Bot.*, vol. 12, p. 583). Lang seemed inclined to the opinion that the facts of apogamy and apospory in ferns lent support to the theory of homologous generations since the

prothallus can so readily take on sporophytic potentialities and the sporophyte develop gametophytes vegetatively. But Lang recognized that the importance of this evidence would be minimized should it be found to depend on changes of nuclear structure. These nuclear changes have been established at least for apogamy, either in the suppression of the reduction phenomena of sporogenesis or by the substitution of asexual nuclear fusions for the sexual act, and the argument for antithetic alternation of generations seems to the writer stronger to-day than ever before.

6. Apospory.

Apospory is the suppression of all processes of sporogenesis and the development of a gametophyte generation directly from the sporophyte. The term was first proposed by Vines (*Jour. of Bot.*, 1878, p. 355) in a discussion of the life history of Chara and adopted by Bower ('86, '87) in a general treatment of the subject based on Druery's ('86a, '86b) discoveries of prothalli developed in place of sporangia directly upon the leaves of *Athyrium filix-fœmina* and its variety *clarissima*. The phenomenon of apospory is best known among the ferns where it has been most extensively studied but so far no cytological investigations have been published. Since apospory results in the development of a gametophyte generation (presumably with the gametophyte number of chromosomes) without the preliminary process of sporogenesis it becomes a very interesting problem to know just how this reduction of the chromosomes is effected.

Apospory is probably not uncommon in the mosses and has also been reported for the liverwort Anthoceros. The independent studies of Pringsheim ('76) and Stahl ('76) established the facts that pieces of the sporophyte stalk (seta) of Hypnum, Amblystegium, Bryum, and Ceratodon when placed on damp soil developed a protonema which in its turn produced leafy moss gametophytes. Stahl also found in Ceratodon that protonemata may arise from the capsule wall and Brizi ('92) discovered a similar development from the atrophied capsule of *Funaria hygrometrica*. Correns ('99a, p. 421) has confirmed the conclu-

sions of Pringsheim and Stahl in species of Funaria, Hypnum, and Amblystegium and obtained negative results in a number of other forms, and presents an excellent review of the subject. Lang (:01) discovered that small pieces of the sporophyte of *Anthoceros lævis* when laid on damp sand produced green outgrowths which took on the structure of young gametophytes and developed rhizoids. These aposporous gametophytes most commonly arose from subepidermal cells, but they may come from any layer of the cortex down to the archesporial cylinder. It seems probable that the mosses at least among the bryophytes are able to reproduce themselves apogamously without difficulty, when normal processes of sporogenesis are interfered with and if the sporophytic tissue is in contact with moisture.

The leptosporangiate ferns, however, furnish the most conspicuous illustrations of apospory as they do of apogamy. Indeed, the two phenomena are known to occur in the same form in a number of instances (*e. g.*, *Athyrium filix-fœmina*, *Nephrodium filix-mas*, *Scolopendrium vulgare*, *Trichomanes alatum*, etc.). Beginning with the discovery by Druery ('86a, '86b) of apospory in *Athyrium filix-fœmina* and its variety *clarissima* the list has steadily grown until now apospory is recorded for about ten forms. In Druery's forms the prothalli developed from arrested sporangia and the spore alone is left out of the life cycle. But Bower ('86) very shortly brought forward in *Polystichum angulare pulcherrimum* a form in which prothalli are developed as simple vegetative outgrowths from the tips of the leaves and the life history is thus shortened by the omission of both spores and sporangia. This condition is exactly analogous to the development of protonemata from vegetative cells of the sporophytes of mosses and Anthoceros. The following year Bower ('87) presented a very full account of the forms of Athyrium and Polystichum just described, and a general discussion of the phenomenon of apospory. Bower ('88) then extended the illustrations of apospory to two species of Trichomanes, of the Hymenophyllaceæ; Farlow ('89) reported it for *Pteris aquilina*, and Druery ('93) in *Lastrea pseudo-mas cristata* and ('95) for *Scolopendrium vulgare crispum*. The exceptional amount of fern variation both in nature and under cultivation has not been

generally appreciated and the studies on apospory and apogamy indicate that much of it is associated with these fundamental modifications of the life history (Druery, :01).

As to the cause of apospory we are as much in the dark as in the case of apogamy. The phenomenon is clearly associated in some forms with disturbances in the normal vegetative life of the sporophytes. This is particularly true in the cases of mosses and Anthoceros and has been suggested for the ferns. Thus aposporous developments in *Pteris aquilina* are from leaves which are generally smaller than the normal and whose margins are curled so that the leaf often appears somewhat withered and is easily recognized at a distance. Bower ('87, p. 322) is inclined to regard the phenomenon in the ferns as a sport and does not consider that it has deep morphological significance or that it offers serious difficulty to the acceptance of the theory of an antithetic alternation of generations.

As we have stated there have been no cytological studies upon apospory but there seem to be two possible explanations. That which is likely to suggest itself first calls for reduction phenomena at the time of the aposporous development by which the nuclei of the sporophytic tissues may come to contain the gametophyte number of chromosomes and are therefore capable of developing the sexual generation. But there is another possibility which has not yet been considered. We know for several of the spermatophytes (Antennaria, Juel, :00; Thalictrum, Overton, :04; Alchemilla, Strasburger, :04c) that the processes of sporogenesis may be suppressed and yet a structure be developed with the morphology of the gametophyte generation. Thus the embryo-sac will contain the usual number of nuclei grouped in the typical manner but these nuclei still have the sporophyte count of chromosomes. It seems probable then that the development of a gametophyte may result through an interference with the normal life history and under conditions favorable to the gametophyte even though the nuclei retain the sporophyte number of chromosomes. And it is possible that some of the aposporous developments in bryophytes and pteridophytes may be of this character. It is quite futile at present to carry this speculation further. What is desired is some cytological facts.

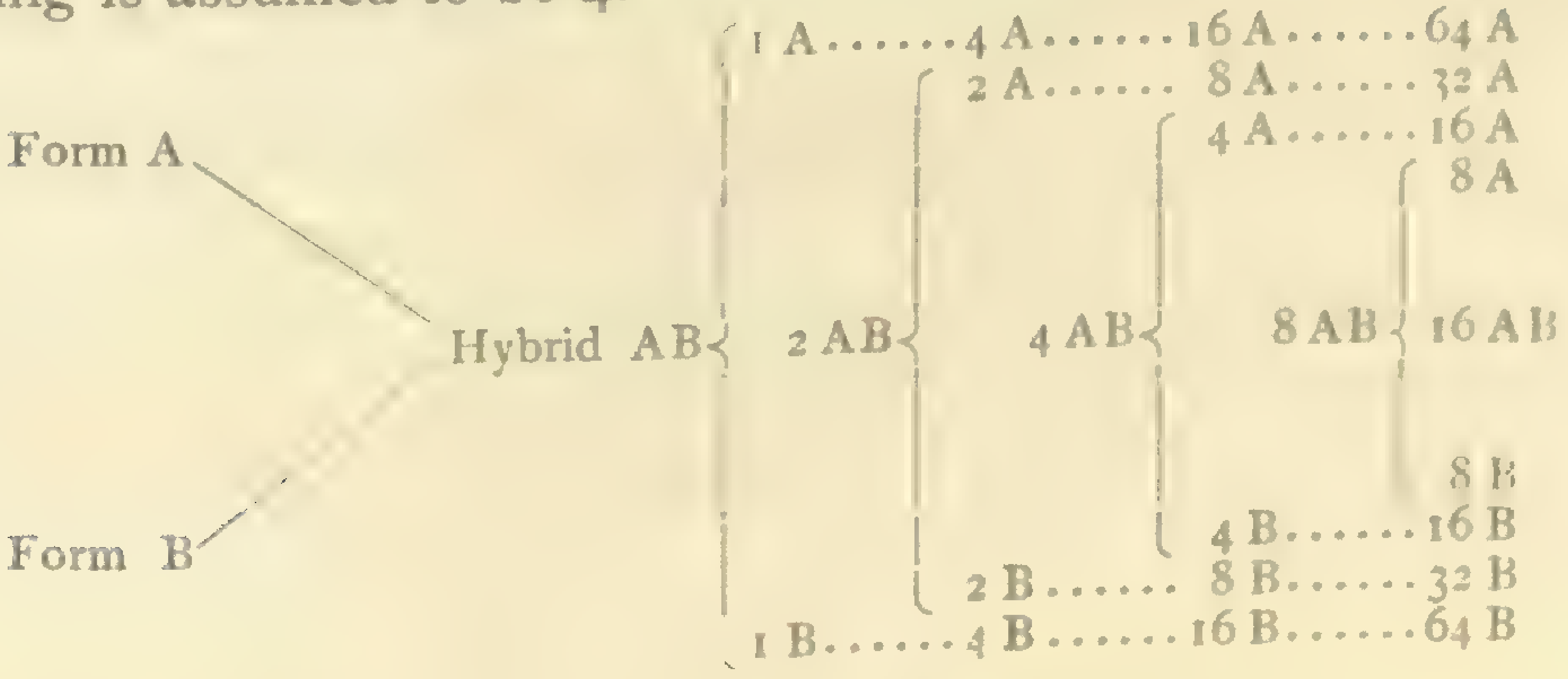
7. Hybridization.

This is not to be a detailed discussion of the facts and theories of hybridization, a subject far too extensive for the purposes of our treatment. We shall only consider some of the bearings of the recent studies on fertilization and reduction phenomena upon the problems of hybridization treating it as a critical phase in the life history of the organisms concerned. Until recently the attempts to formulate definite laws for the formation of hybrids and their progeny upon a physical basis have not been satisfactory. But the work of a number of breeders all of whom owe their results in large part to a quick appreciation of Mendel's epoch-making contributions have brought much order out of what was a very confused subject. And accompanying the work of this group must be added the equally important conclusions of a number of cytologists whose investigations on the structure and behavior of nuclei in the critical periods of fertilization and chromosome reduction have done much to place Mendelian principles upon a cytological basis. We shall deal with the work of the latter group, for their contributions concern intimately the subject matter of these papers.

We shall not review the conclusions of Mendel except to point out the relations of some of his principles to cytological phenomena. The two papers of Mendel appeared in the proceedings of a natural history society of Brünn, Austria, under the dates 1865 and 1869. They lay buried until 1900 when De Vries, Correns, and Tschermak independently rediscovered them and called the attention of the scientific world to their worth. Soon after, Bateson published a translation of the two papers (*Mendel's Principles of Heredity*, Cambridge, 1902) with an introduction and a defense against the criticisms of Professor Wheldon. There have naturally been many reviews and short discussions of Mendelian theories and among them that of Castle entitled "Mendel's Laws of Heredity" (*Science*, vol. 18, p. 396, 1903) and Professor Bailey's "Lecture IV" in *Plant Breeding*, 1904, will perhaps give the reader the clearest and most concise statements.

The most striking feature of Mendel's investigations and those

of others, who have confirmed his conclusions, is the discovery in a number of animals and plants that the germ cells of the hybrid may be pure with respect to certain characters of the parents which are crossed. This principle is not without exceptions where the conditions are apparently complicated by unusual factors but the phenomenon when present is so striking as to command immediate attention and call for an explanation on a cytological basis. The purity of the germ cells of hybrids means in the words of Castle that "the hybrid, whatever its own character, produces ripe germ cells which bear only the pure characters of one parent or the other." Thus if two forms A and B are crossed the hybrid will have embodied in itself the characters AB, one of which however may lie latent, *i. e.*, may not be visible in the hybrid. Such a latent character when present is termed recessive while the prominent character is termed dominant. In a simple case some of the offspring of the hybrid AB will be found to have the character of A alone, some of them of B alone, and some of them will again have the mixed characters AB. If experiments are carried out on an extensive scale the proportions of these offspring from the hybrid may exhibit the remarkable fact that there are about twice as many forms of AB as either A or B, *i. e.*, the proportions of A's, AB's, and B's are in the ratio of 1 : 2 : 1. Furthermore the offspring of A when bred among themselves remain absolutely true producing a succession of pure forms all A's and the same results follow when the offspring of B are closely bred. But when forms with the mixed characters AB are bred with one another their offspring break up as before into three types A, AB, and B in numerical proportions expressed by the same ratio 1 : 2 : 1. The history is simply told in the following diagram where the number of offspring is assumed to be 4.



This remarkable proportion of forms derived from the hybrids AB, *i. e.*, A, AB, and B in the ratio 1 : 2 : 1 can only be explained on the assumption that the germ cells of the hybrid are pure with respect to the characters of either one or the other of the parents. The gametes from the hybrid, with the pure characters of either A or B and approximately equal in number, may unite with one another in three possible combinations AA, AB, or BB forming three types of offspring, one pure A, another mixed AB, and the last pure B. By the law of chance the proportions of these combinations (AA, AB, and BB) in a simple case will be in the ratio 1 : 2 : 1. This assumption of the purity of the germ cells of hybrids has been found to conform with the facts in a number of simple experiments where two characters such as A and B were sharply contrasted. When one of the characters in the hybrid is dominant and the other recessive the ratio can be expressed as D : DR : R as 1 : 2 : 1 which is merely a substitution of D and R for the characters A and B.

There are of course many factors which tend to modify the ratios as stated above and complicate the results. Thus the normal number of gametes may be of varying vigor and mortality so that there will be proportionately more or less of one type of fusion than is called for by the law of chance. Sometimes the characters of the parents remain evenly balanced in the hybrid and refuse to split up in the succeeding generations, remaining in a stable union in the germ cells produced by the hybrid. Such conditions prove exceptions both to the law of dominance and to that of purity of the germ cells. From these exceptions and particularly the last it is difficult to believe that any large proportion of the germ cells is *absolutely* pure, *i. e.*, bearing only the pure characters of one parent or the other. However, there is much evidence from our knowledge of the distribution of the chromosomes from one generation to the next, that certain relations are possible in the separation of germ plasm which approximate the ratios of Mendel's law and while rarely giving *absolutely* pure germ cells nevertheless do make possible a large proportion of *relatively* pure cells.

Let us examine now the chromosome history as a possible physical basis for the Mendelian principles. Such considerations

must rest on the assumption of what is termed the individuality of the chromosome. This means that the chromosome is believed to be a permanent organ of the cell which never loses its organic entity although the form may be frequently obscured, as in the resting nucleus, and which reproduces by fission during mitosis. We have given in other connections the evidence upon which the above view rests, evidence accumulated from the studies of the critical periods of gametogenesis, fertilization, and sporogenesis (with its reduction phenomena) in plants and of gametogenesis and fertilization in animals. All investigations indicate that paternal and maternal chromosomes maintain complete independence in the sexually formed cell or fertilized egg and in the mitoses of cleavage so far as these have been followed. Also, descendants of the chromosomes which became associated with fertilization have been recognized by their form at the end of the life history during the reduction phenomena of gametogenesis in certain animals (Sutton, :02, :03; Montgomery, :04) and of sporogenesis in the hybrids of Drosera (Rosenberg, :04a, :04b). Furthermore, the entire history of chromosome reduction in both animals and plants finds a satisfactory explanation only in the belief that descendants of maternal and paternal chromosomes are distributed as organic entities by the peculiar mitoses of this period.

There is a general agreement that the somatic chromosomes of animals and the sporophytic of plants become grouped in pairs to form bivalent structures before the heterotypic mitosis of the reduction division whether this be present in the primary gametocyte (animals) or the spore mother-cell (plants). The bivalent chromosomes (pairs of chromosomes, dyads) may become transformed into tetrads before the heterotypic mitosis by a division of each chromosome in the pair, as is characteristic of animals, or this division may be delayed until a somewhat later period during the heterotypic mitosis, as in plants. We are not concerned now with the dispute as to how the pairs of chromosomes come to lie side by side to form the bivalent structure or how tetrads are developed, activities which may indeed be various in different types and which will only be understood by a greater body of observations than we have at present (see dis-

cussion of "Reduction of Chromosomes"). The important point for us is the belief that the appearance of the bivalent chromosomes during reduction is due to the temporary union of somatic or sporophytic chromosomes in pairs and further that the reducing divisions distribute the members of the pair, which are believed to be descendants of the maternal and paternal chromosomes of the previous generation, as organic entities to the generation which is to follow.

It is difficult to overestimate the importance of this generalization. If the program prove to be correct as stated above and if the chromosome is established beyond doubt as a self-perpetuating organ of the cell and a bearer of hereditary characters we have then the possibility of studying the actual manner in which these structures are passed on from one generation to the next and perhaps determine the ratios or combinations through which the distribution is effected. The difficulty of making an exact determination of ratios in any form so far studied lies in our inability to distinguish the chromosomes of maternal and paternal origin. There is much evidence that the pairs of somatic and sporophytic elements, which form the bivalent chromosomes of the reduction mitoses of animals and plants respectively, are of different parentage but we do not know whether or not there is any rule in the arrangement of the pairs on the spindles of these mitoses although this is hardly to be expected. Cannon (:02, :03a) and others have held that the mitoses of reduction brought about the complete separation of the maternal and paternal chromosomes so that two of the resultant four nuclei contain chromosomes from one parent and two from the other, and the germ cells are in consequence *absolutely* pure in character. But this view was soon shown by Sutton (:03, p. 233; accepted by Cannon, :03b) to be at variance with the facts of breeding for if germ cells of hybrids are *absolutely* pure there could be no further change by cross-breeding and the first cross would be repeated over and over again without any divergence from the type, which is contrary to experience and fact. The pairs of chromosomes are probably arranged in every possible order and the maternal and paternal elements are distributed in every possible combination by the reducing

divisions. If this is true then by the law of chance the proportions of germ cells of the hybrid which are *absolutely* pure (containing chromosomes entirely from one parent) would be small. Likewise there would be a small proportion of germ cells in which the paternal and maternal chromosomes are equally distributed. And in contrast to these two groups the great majority of germ cells would have a marked preponderance of chromosomes derived from one parent or the other and this condition may be termed one of *relative* purity.

We shall now summarize the cytological evidence for the conclusions of the paragraph above, first with respect to the actual distribution of the somatic and sporophytic chromosomes as entities during the mitoses of reduction, and second as to the probability of the bivalent chromosomes consisting of a pair of maternal and paternal elements. The evidence on the first point has been treated as regards plants in our own account of "Reduction of the Chromosomes" and need not be repeated. With respect to the possibilities of distinguishing maternal and paternal chromosomes throughout a life history and especially at the period of chromosome reduction we must consider briefly the remarkably favorable studies of Sutton, Montgomery, Moenkhaus, Baumgartner, and Rosenberg.

Sutton (:02, :03) discovered in the "lubber grasshopper" (*Brachystola magna*) a form in which the somatic chromosomes, 23 in number, are markedly different in size, presenting a graded series with respect to pairs in which the two elements are approximately equal. There are then 11 types of chromosomes in two groups, a pair of each type, and in addition an accessory chromosome which remains apart from the rest in a special vesicle of its own. These two sets of 11 chromosomes appear with regularity throughout the mitoses leading up to the reduction divisions of spermatogenesis. Previous to the reducing divisions the chromosomes of each pair become closely associated end to end so that 11 threads appear which form 11 bivalent chromosomes (dyads) that later become tetrads through the division of each chromosome in the pair. Sutton concludes that the somatic chromosomes which make up each bivalent structure conjugate during synapsis and that the transverse fission which

appears during the formation of the tetrad simply separates the two somatic chromosomes of the pair, while the longitudinal fission is the usual division of chromosomes, appearing prematurely at this time. The conclusion is natural that the two series of the 11 pairs consist of maternal and paternal chromosomes which are distributed as organic entities by the reducing divisions. But there are no reasons for supposing that all of the paternal chromosomes will pass into one set of germ cells and all of the maternal into another but rather that the ratios of distribution will be by the law of chance according to which the great majority of germ cells will have a marked preponderance of chromosomes from one parent or the other, and will therefore be *relatively* pure. An exceedingly small proportion of germ cells may, by the law of chance, contain chromosomes entirely of maternal or paternal extraction, and an equally small proportion may contain 6 chromosomes of one parent and 5 of the other. The accessory chromosome divides but once during the mitoses of spermatogenesis so that two of the spermatozoids have 11 chromosomes and two 12. No accessory chromosome appears in the mitoses of oögenesis indicating that the female insect lacks this structure which confirms the belief of McClung (:02) and others that the accessory chromosome is a determinant of the male sex.

Montgomery in a series of studies upon insects and Amphibians, which are summarized in a recent paper (:04), reached conclusions in striking support of the theories of the individuality of the chromosomes, the association of pairs of chromosomes during synapsis to form bivalent structures and the probability of the elements of each pair (bivalent chromosomes) being of maternal and paternal origin respectively. His results on the last point are of especial interest in relation to hybridization. In a large number of insects, chiefly Hemiptera, Montgomery has found pairs of chromosomes, which he terms heterochromosomes, much smaller or much larger than the others and these may be followed through mitosis from one nucleus to another. The heterochromosomes of each pair are known to unite with one another during synapsis to form the bivalent chromosomes of the reduction mitoses and they then become separated, each

dividing once, so that every germ cell receives a single heterochromosome of whatever sort. Fertilization then brings the heterochromosomes together again in pairs until the next period of chromosome reduction. This history is then parallel to Sutton's account of the lubber grasshopper (Brachystola), the difference being that the latter form presents a remarkably graded set of paired chromosomes. Montgomery regards the small chromosomes and the accessory chromosome as structures tending to disappear in a process of evolution from a higher chromosomal number to a lower.

Moenkhaus (:04) crossed reciprocally two species of fishes (*Fundulus heteroclitus* and *Menidia notata*) and obtained hybrid embryos which reached an advanced stage of development. The chromosomes of the parents are readily distinguished by size and form. These chromosomes were followed throughout the development of the hybrid embryo and were found to retain their peculiarities so that the two sets may be easily separated in favorable tissues. This investigation furnishes some of the strongest evidence of the individuality of the chromosome and the complete independence throughout the life history of the two sets derived from each parent. Could these hybrid embryos be raised to maturity we should expect to find during spermatogenesis and oögenesis an association of the chromosomes in pairs, those of paternal extraction with those of maternal to form the bivalent chromosomes preliminary to the reducing divisions, and a distribution to the sexual cells in varying proportions which would, however, give a very large ratio of *relatively* pure germ cells.

Baumgartner (:04) in studies upon spermatogenesis in the cricket (Gryllus) was able to distinguish the chromosomes by their form, following them through the mitoses of reduction. Most of the chromosomes have the form of straight or bent rods but there are apparently two rings in each set in *G. domesticus*. The variation in the form of chromosomes in the nucleus is well known but it has not been supposed that a definite form might be characteristic of an element and be maintained throughout the successive mitoses of a life history as seems probable from Baumgartner's results.

Rosenberg's (:04a, :04b) studies on hybrids of *Drosera rotundifolia* (with ten chromosomes in the gametophyte) and *D. longifolia* (with twenty chromosomes) offer clear evidence that the chromosomes which unite in pairs to form bivalent structures preliminary to the reduction phenomena of sporogenesis are of different parentage. The sporophyte number of chromosomes in the hybrid is thirty, as would be expected. The reduced number appearing at the first mitosis of sporogenesis is, however, not fifteen but twenty chromosomes, ten of which are plainly double the size of the other ten. The explanation of this interesting condition is that the ten chromosomes of *D. rotundifolia* unite with one half of the twenty chromosomes of *D. longifolia* giving ten large bivalent structures accompanied by the ten chromosomes of *D. longifolia* which are without mates. This explanation finds clear support in the facts that the chromosomes of *D. rotundifolia* are larger than those of *D. longifolia* and that the bivalent structure consists of a larger and a smaller element thus giving clear evidence that the pairs of chromosomes which unite in Drosera are of different parentage. The single chromosomes which are without mates may pass to one or the other of the poles of the spindle or may be left behind when the daughter nuclei are formed.

This group of investigations illustrates very clearly the character of the evidence that is leading many biologists to assign to the chromosomes the functions of bearing and distributing hereditary characters. The question at once comes up as to whether or not the chromosomes may differ among themselves to a greater or less extent even in the same species or individual. Montgomery, Sutton, with others, have established a difference in the *size* of chromosomes. Baumgartner distinguishes differences in *form* in the same species and the studies of Moenkhaus and Rosenberg have shown that the chromosomes of different parents may retain their peculiarities of *form* in hybrids and be really separated. To these investigations should be added the recent conclusions of Boveri (:02, :04), that chromosomes actually differ in *function*. Boveri found that the chromosomes of eggs of echinoderms that were fertilized by two or more sperms are distributed by multipolar spindles to a varying number of

blastomeres which in consequence received a varying number and assortment of chromosomes. Boveri then separated these blastomeres and followed their independent development into larval stages which exhibited marked differences in form that could be correlated with the irregularities in the number of chromosomes contained in each, thus suggesting that specific chromosomes have specific functions. With this sort of evidence accumulating from both the morphological and physiological side it is not surprising that many biologists believe that specific characters are actually held or are controlled by chromosomes or groups of chromosomes.

Such views of course presuppose that the chromosomes retain a high degree of independence of one another and that variation is expressed chiefly through different combinations of chromosomes and not by modifications of the chromosomes themselves. Yet there is strong evidence of an actual mixing or interchange of the idioplasm among the chromosomes. This possibility which is of course contradictory to the view of the *complete* independence of the chromosomes finds its chief support in the close association of the pairs of chromosomes with the organization of the reduced number of bivalent structures during synapsis. These pairs have been reported so intimately united as to be actually fused. Allen (:05) has described for Lilium the union of two sets of chromomeres, one believed to be derived from a paternal spirem and the other from a maternal, which come to lie side by side during synapsis and unite to form a spirem with a single series of fusion chromomeres. This single (fusion) spirem later splits longitudinally and the two halves are regarded as again representing maternal and paternal spirems but there are evidently opportunities during the period of fusion for significant reciprocal interaction between the two idioplasms. This conception of the fusion of idioplasm from the two parents is an old view which has been held by such well known biologists as Hertwig and Strasburger.

De Vries (:03) has recently discussed the significance of the pairing of chromosomes before the heterotypic mitosis in relation to the theory of pangenesis. He conceives the paternal and maternal chromosomes as coming together during synapsis in

homologous pairs so that corresponding pangenes or groups of pangenes are brought together and that there may be a mutual interchange or transfer of idioplasm with the result that the chromosomes after separating may contain a mixed set of pangenes although each is supposed to have a complete assortment. The interchange makes possible all forms of combinations of the pangenes in the two sets, according to the laws of chance, which might be expressed in proportions that would approximate in some cases the ratios of Mendel. If the parents are widely different from one another their idioplasm may not correspond sufficiently to make possible this union and interchange of pangenes so that the process is suppressed and the hybrid is sterile.

Allen (:05, p. 247) points out that the union of two spirems during synapsis with the fusion of two sets of chromomeres, according to his account of the lily, offers a number of possibilities with respect to the constitution of idioplasm following the reduction mitosis. (1) There may be such a fusion of elementary units that a single idioplasm is formed different from either parent which would of course be distributed equally to the reproductive cells by the subsequent double longitudinal fission of the single (fusion) spirem. This would be expected to give hybrids of much the same form in every instance and these would remain stable (constant). (2) There may be a greater or less mixing or modification of units but without the actual union and formation of a new idioplasm in the hybrid. Then by the splitting of the single (fusion) spirem there might result a distribution of the mixed idioplasm following ratios or proportions approximating Mendel's law. (3) There may be in part a fusion and in part a mixing of idioplasm which would be expected to result in a varied combination of parental characters in the offspring. (4) While the chromosomes may be distributed according to ratios similar to Mendel's principles their respective characters may be greatly modified by their temporary union during synapsis. (5) Portions of the idioplasm may interact upon one another so that when they are separated by the reduction mitoses their character has become variously modified. (6) Finally, Allen, of course, recognizes the possibility that parental

idioplasm may be separated so purely by the longitudinal splitting of the single (fusion) spirem or through the distribution of unmodified sporophytic or somatic chromosomes as to give *absolutely* and *relatively* pure germ cells through Mendelian laws.

Allen's discussion, very briefly summarized above, is important for the emphasis which is laid upon the significance of a possible mixing of the parental idioplasms in the more or less complete union of chromatic material, which is generally recognized as characteristic of synapsis. There is a general tendency to rest content when the chromosomes are accounted for as units while they are merely the grosser form of expression of the idioplasm whose final architecture is intricate far beyond our present powers of analysis. Allen's own studies upon the events of synapsis in the lily with the regular fusion in pairs of chromomeres of different parentage may well cause one to hesitate in a full acceptance of the chromosome as fixed and unchanged in its organic constitution throughout the life history. The phenomenon of hybridization is far too complex to be explained in terms of simple ratios and while some characters may be paired or correlated in proportions that can be expressed by mathematical formulæ there is little probability that the assemblage of characters which make the species can be so definitely grouped as the strongest disciples of Mendel may hope. However, a great forward step has been taken and we may expect important results from the empirical methods so clearly defined by Mendel and by the close investigation that cytologists are making of the history of idioplasmic structures (chromosomes) during ontogeny.

8. Xenia.

Xenia is the "immediate or direct effect of pollen on the character of seeds and fruits." The term was first proposed by Focke, in 1881, and is now well established. Xenia has long been known to the plant breeder as one of the most interesting and puzzling problems of hybridization. The botanist has naturally looked for the results of hybridization in the development of the embryo from the seed since this structure has received

the substance of the sperm nucleus of the male parent. But facts have clearly shown that the pollen may also affect the structure of the endosperm in the seed as well as cause the development of the embryo. Since the endosperm holds no genetic relation to the embryo it has seemed very remarkable that it should take on hybrid qualities. It has also been claimed that other regions of the seed or fruit, such as portions of the pericarp were also affected, but it is doubtful whether this is really so or at least whether such changes are truly a feature of the protoplasmic structure and thus deeply seated in the organism as a feature of hybridization.

It is only within recent years that a satisfactory theory has been suggested for the influence of pollen outside of the embryo. And this explanation rests on the discovery of the activities of the second sperm nucleus which enters the embryo-sac and which is known in some cases to unite with the polar nuclei constituting a triple nuclear fusion within the sac that is generally known as "double fertilization." We have briefly referred to the phenomenon in the latter part of the account of "Asexual Cell Unions and Nuclear Fusions" in Section IV and shall take it up now in greater detail. The best account of xenia is a very clear treatment by Webber, in 1900.

The explanation of xenia upon the facts of "double fertilization" was proposed almost simultaneously by De Vries ('99, :00), Correns ('99b), and Webber (:00). Double fertilization was first observed by Nawaschin ('98) in Lilium and Fritillaria and shortly after was described in greater detail by Guignard ('99b) in other species of the same genera and in Endymion. Since these discoveries the phenomenon has been reported by a number of investigators in many other forms representing widely divergent groups in the Monocotyledonæ and Dicotyledonæ and there is every reason to believe that it is widespread in the angiosperms. A review of the recent literature is given by Coulter and Chamberlain (*Morphology of the Angiosperms*, 1903, p. 156). There is no fixed order in the events of the triple nuclear fusion of "double fertilization." The polar nuclei may have united at the time when the pollen tube enters the embryo-sac, in which case the second sperm nucleus coalesces with an organized fusion

endosperm nucleus. Or, the two polar nuclei and the sperm nucleus may all three fuse together practically simultaneously. And again the sperm nucleus may unite first with one of the polar nuclei and the second be drawn later into the triple fusion. But no cases seem to have been reported in which but one polar nucleus unites with the sperm leaving the other free although such a combination may be expected. Also, no one has observed an independent division of the sperm nucleus within the endosperm, although as we shall see, there are reasons for believing that such a development may sometimes take place.

We have already given in Section IV the reason why these triple nuclear fusions may be kept apart from sexual phenomena since we have no knowledge of the phylogenetic history of the processes involved. It seems best at least for the present to regard the phenomenon as a special development associated with the peculiar and highly specialized conditions within the embryo-sac. This detailed and highly difficult problem of phylogeny has no especial bearing on the physiological features of xenia with which we are at present concerned.

The best understood examples of xenia are found in the hybrids of maize and are clearly described in the very interesting paper of Webber (:00). As is well known, some of the varieties of corn are distinguished among other characters by the color of the kernels, which are blue, red, yellow, and white, and also by the surface, which is smooth in the starchy corns (flint or dent) and wrinkled in the sugary sweet corns. When well marked pure races are grown out of reach of chance cross pollination, the offspring remain true to their seed characters but it has long been known that the varieties of corn hybridize very readily so that when grown close together the ears will very frequently present seeds mixed as to color and texture. Thus when exposed to cross-pollination a corn which is characteristically yellow or white may bear blue or red kernels or a form with wrinkled and starchy kernels may develop smooth starchy corn if varieties with these characters are in the vicinity. The color character is known to lie in these examples in the outer layer of the endosperm (aleurone layer) and of course the food material whether prevailingly starch or sugar, which gives the

surface a texture smooth or wrinkled, is stored within the endosperm.

The clearness of xenia in the maize has led to a number of careful studies on cross-pollination beginning with the work of Vilmorin (1866), Hildebrand (1867), and Friedrich Körnicke (1872). The possible explanation of xenia in maize through "double fertilization" which introduces qualities of the male parent from the pollen into the endosperm was suggested by experiments of De Vries on hybridizing maize in the summers of 1898–99 and Correns and Webber in 1899. De Vries ('99, :00) pollinated a wrinkled-seeded sugar corn from a variety of smooth starchy corn and obtained smooth starchy kernels which when cultivated in the succeeding summer were found to be true hybrids. He concluded that this furnished experimental proof that the endosperm of the sugar corn was affected by the entrance of a sperm nucleus from the starchy variety according to the theory of "double fertilization" proposed by Nawaschin ('98).

Correns ('99b) in the same year expressed similar conclusions in a clear statement of the theoretical aspects of the problem of xenia as found in *Zea mays*. Correns advanced a number of propositions some of which should be noted for their speculative interest. Thus he states (proposition 7) that the influence of the new pollen (*i. e.*, from the male parent of the hybrid) is expressed as xenia only in the endosperm and (proposition 8) only in the pigment present or the chemical nature of the reserve material whether starchy or sugary. If the two races differ only in the presence of one character, as in the color of the aleurone layer, that character is only found in xenia when brought by the pollen (proposition 10). Xenia is then only expressed in a hybrid (proposition 14) by the formation of a pigment which the race of the female parent does not possess or of a more complicated chemical compound (such as starch) in place of a simpler (as dextrin). Correns (:01) later presented in a lengthy paper, beautifully illustrated, the full results of his studies on xenia in maize with a discussion of the hybrids.

Webber (:00) also simultaneously with De Vries and Correns conducted extensive experiments in hybridizing a number of

varieties of corn distinguished by the color of the kernels, which were white, yellow, red, or blue and by the texture whether smooth, hard, and starchy (dent or flint corn) or wrinkled and sugary (sweet corn). The results of his investigation are admirably presented with excellent illustrations. He found that the smooth kernel and starchy endosperm of the dent and flint corn were transmitted very conspicuously as xenia when these forms were employed as the male in crossing with the sweet corns whose kernels are wrinkled and sugary. The characters of the sweet corns do not seem to be expressed as xenia when smooth, starchy, dent corn is used as the female member of the hybrid. This experiment would seem to support Correns' proposition number 14 that a more complicated compound is always formed in xenia in place of a less complex. But Webber found that flint corn, which is smooth and starchy, when pollinated with a form of sweet corn developed the wrinkled kernel and sugary type of endosperm of the male member indicating that this rule of Correns is not universal. And McClure ('92) obtained similar results in crossing a white dent race with pollen of Black Mexican which is a sugar corn with black kernels. The product in this case showed xenia clearly in having the wrinkled blue-black kernels of the male sugar corn.

Some of Webber's most striking results were obtained in pollinating yellow and white corns with blue-black and red races. The color was transmitted as xenia in a most striking manner. Webber agrees with other authors that the color is only present in the endosperm of the kernels. Thus the red of certain dent corn, which lies in the pericarp, is not passed on as xenia and McClure observed the same facts in experiments with cranberry corn whose color lies in the seed coat and is not transmitted when employed as the male member in crossing with white corns. Webber's experiments show, as do those of other investigators, that the absence of color in the kernels of the male parent does not seem to affect the tint of the kernels when the female is markedly colored, in agreement with Correns' proposition number 10. But Webber is not convinced that some influence might not be exerted on colored corn when pollinated from races with colorless endosperm, because of certain experiments on variegated xenia which will be described presently.

These experiments of De Vries, Correns, Webber, and others have established experimentally the facts of xenia and Nawaschin's theory of double fertilization seems to offer the only explanation of the phenomenon. But it was left to Guignard (:01) to make the concluding observation that a second sperm nucleus does actually enter into the composition of the endosperm of maize, and this fact clinched the argument which up to this time had been a speculation.

Webber has made a very important addition to the theory of "double fertilization" as an explanation of xenia in some observations and speculations on a mottled condition which is sometimes present when white corns are pollinated by colored. He found that the color was sometimes only transmitted in spots as when Hickory King was pollinated by Cuzco, or perhaps only half a kernel may be colored. Webber offers the hypothesis that the second sperm nucleus may enter the embryo-sac but instead of uniting with the two polar nuclei to form a triple fusion may itself divide separately and thus gives rise to a progeny very different from the other endosperm nuclei. There might then be two sets of nuclei in the endosperm one of which is composed of nuclei which would come directly from the male parent. These latter then might become distributed throughout the embryo-sac but would tend to remain in groups as multiplication progressed and would certainly be expected to influence the character of the tissue which is formed later when the walls are developed around the free nuclei. As Webber expresses it, there might be formed islands of tissue in the endosperm whose cells contain nuclei derived directly from the second sperm and such tissue would be expected to show characters of the male parent in spots as xenia. Again, if the sperm nucleus should unite with only one of the polar nuclei and the other should give rise to an independent progeny we should expect similar mixed conditions in the endosperm, with xenia only expressed in the areas dominated by nuclei containing material derived from the sperm.

There have been reported illustrations of xenia in tissues outside of the endosperm but we are fully justified in awaiting their confirmation before accepting them, especially since some

have failed to stand the test of critical investigation, in the light of the present theory. Thus certain investigators have reported xenia in the color of the seed coats of certain peas. But Giltay ('93) in a series of experiments found no instance where color was transmitted to these tissues. The pigments in these plants lie in the cotyledons of the embryo which of course are readily visible through the thin coats of the seed. While the present theory of xenia is very recent and has been critically applied in few forms, it seems thoroughly satisfactory in every particular with no clearly established evidence against it.

LITERATURE CITED IN SECTION V, "THE PLANT CELL."

ALLEN.

:04. Chromosome Reduction in *Lilium canadense*. *Bot. Gaz.*, vol. 37, p. 464.

ALLEN.

:05. Nuclear Division in the Pollen Mother-Cells of *Lilium canadense*. *Annals of Bot.*, vol. 19, p. 189.

ATKINSON.

'99. Studies on Reduction in Plants. *Bot. Gaz.*, vol. 29, p. 1.

BAUMGARTNER.

:04. Some New Evidence for the Individuality of the Chromosomes. *Biol. Bull.*, vol. 8, p. 1.

BELAJEFF.

'98. Ueber die Reductionstheilung des Pflanzenkernes. *Ber. d. deut bot. Gesellsch.*, vol. 16, p. 27.

BEARD.

'95. On the Phenomena of Reproduction in Animals and Plants. Antithetic Alternation of Generations. *Annals of Bot.*, vol. 9, p. 441.

BERGHS.

:04a. Depuis le spirem jusqu'aux chromosomes mûrs dans la microsporogénèse d'*Allium fistulosum* et de *Lilium lancifolium* (*speciosum*). *La Cellule*, vol. 21, p. 173.

BERGHS.

:04b. Depuis la sporogonie jusqu'au spireme définitif dans la microsporogénèse de l'*Allium fistulosum*. *La Cellule*, vol. 21, p. 383.

Berghs.

:05. La microsporogénèse de *Convallaria maialis*. *La Cellule*, vol. 22, p. 43.

Bitter.

:04. Parthenogenesis und Variabilität der *Bryonia dioica*. Abh. nat. Ver. Brem., vol. 18, p. 99.

Blackman.

:04a. On the Fertilization, Alternation of Generations, and General Cytology of the Uredineæ. *Annals of Bot.*, vol. 18, p. 323.

Blackman.

:04b. On the Relation of Fertilization to "Apogamy" and "Parthenogenesis." *New Phytologist*, vol. 3, p. 149.

Boveri.

:02. Ueber mehrpolige Mitosen als Mittel zur Analyse des Zellkerns. *Verh. d. phys.-med. Gesellsch. Würzburg.*, vol. 35.

Boveri.

:04. Ergebnisse über die Konstitution der chromatischen Substanz des Zellkerns. Jena, 1904.

Bower.

'86. On Apospory in Ferns. *Jour. Linn. Soc. London, Bot.*, vol. 21, p. 360.

Bower.

'87. On Apospory and Allied Phenomena. *Trans. Linn. Soc. London, Bot.*, II, vol. 2, p. 301.

Bower.

'88. On some Normal and Abnormal Developments of the Oöphyte in Trichomanes. *Annals of Bot.*, vol. 1, p. 269.

Brizi.

'92. Apunti di teratologia briologica. *Ann. d. Instit. Bot. d. Roma*, vol. 5, p. 53.

Calkins.

'97. Chromatin Reduction and Tetrad-formation in Pteridophytes. *Bull. Torrey Bot. Club*, vol. 24, p. 101.

Calkins.

:01. The Protozoa. New York, 1901.

Chamberlain.

:05. Alternation of Generations in Animals from a Botanical Standpoint. *Bot. Gaz.*, vol. 39, p. 137.

Cannon.

:02. A Cytological Basis for the Mendelian Laws. *Bull. Torrey Bot. Club*, vol. 29, p. 657.

Cannon.

:03a. The Spermatogenesis of Hybrid Cotton. *Bull. Torrey Bot. Club*, vol. 30, p. 133.

CANNON.

:03b. The Spermatogenesis of Hybrid Peas. *Bull. Torrey Bot. Club*, vol. 30, p. 519.

CORRENS.

'99a. Untersuchungen über die Vermehrung der Laubmoose durch Brutorgane und Stechlinge. Jena, 1899.

CORRENS.

'99b. Untersuchungen über die Xenien bei *Zea Mays*. *Ber. d. deut. bot. Gesellsch.*, vol. 17, p. 410.

CORRENS.

:01. Bastarde zwischen Maisrassen mit besonderer Berücksichtigung der Xenia. *Bibliotheca botanica*, Heft 53. Stuttgart, 1901.

COULTER AND CHAMBERLAIN.

:03. Morphology of the Angiosperms. New York, 1903.

COULTER AND LAND.

:05. Gametophytes and Embryo of *Torreya taxifolia*. *Bot. Gaz.*, vol. 39, p. 161.

DAVIS.

'96. Development of the Procarp and Cystocarp in the genus Ptilota. *Bot. Gaz.*, vol. 22, p. 353.

DAVIS.

'99. The Spore Mother-Cell of Anthoceros. *Bot. Gaz.*, vol. 28, p. 89.

DAVIS.

:01a. Nuclear Studies on Pellia. *Annals of Bot.*, vol. 15, p. 147.

DAVIS.

:01b. The Origin of Sex in Plants. *Pop. Sci. Month.*, vol. 60, p. 66.

DAVIS.

:03a. The Evolution of Sex in Plants. *Pop. Sci. Month.*, vol. 62, p. 300.

DAVIS.

:04a. Oögenesis in Vaucheria. *Bot. Gaz.*, vol. 38, p. 81.

DE BARY.

'78. Ueber apogame Farne und die Erscheinung der Apogamie im Allgemeinen. *Bot. Zeit.*, vol. 36, p. 449.

DE VRIES.

'99. Sur la fécondation hybride de l'albumen. *Compt. Rend. d. Séan. d. l'Acad. d. Sci.*, vol. 129, p. 973.

DE VRIES.

:00. Sur la fécondation hybride de l'endosperm chez le maïs. *Rev. Gen. d. Bot.*, vol. 12, p. 129.

DE VRIES.

:03. Befruchtung und Bastardierung. Leipzig, 1903.

DIXON.

'95. The Nuclei of *Lilium longiflorum*. *Annals of Bot.*, vol. 9, p. 663.

Dixon.
'96. On the Chromosomes of *Lilium longiflorum*. *Proc. Roy. Irish Acad.*, vol. 3, p. 707.
Dixon.
:00. On the First Mitosis of the Spore Mother-cells of Lilium. *Proc. Roy. Irish Acad.*, vol. 6, p. 1.
Druery.
'86a. Observations on a Singular Mode of Development in the Lady-fern (*Athyrium filix-fœmina*). *Jour. Linn. Soc. London, Bot.*, vol. 21, p. 354.
Druery.
'86b. Further Notes on a Singular Mode of Reproduction in *Athyrium filix-fœmina*, var. *clarissima*. *Jour. Linn. Soc. London, Bot.*, vol. 21, p. 358.
Druery.
'93 Notes on an Aposporous Lastrea (Nephrodium). *Jour. Linn. Soc. London, Bot.*, vol. 29, p. 479.
Druery.
'95. Notes upon Apospory in a Form of *Scolopendrium vulgare*, var. *crispum*, etc. *Jour. Linn. Soc. London, Bot.*, vol. 30, p. 281.
Druery.
:01. Fern Variation in Great Britain. *Bot. Gaz.*, vol. 31, p. 347.
Ernst.
:01. Beiträge zur Kenntniss der Entwickelung des Embryosackes und des Embryo (Polyembryonie) von *Tulipa gesneriana* L. *Flora*, vol. 88, p. 37.
Farlow.
'74. An Asexual Growth from the Prothallus of *Pteris cretica*. *Quart. Jour. Mic. Sci.*, vol. 14, p. 266.
Farlow.
'89. Apospory in *Pteris aquilina*. *Annals of Bot.*, vol. 2, p. 383.
Farmer.
'94. Studies in Hepaticæ: On *Pallavicinia decipiens* Mitten. *Annals of Bot.*, vol. 8, p. 35.
Farmer.
'95a. Spore-formation and Karyokinesis in Hepaticæ. *Annals of Bot.*, vol. 9, p. 363.
Farmer.
'95b. On Spore-formation and Nuclear Division in the Hepaticæ. *Annals of Bot.*, vol. 9, p. 469.
Farmer.
'95c. Further Investigations on Spore-formation in *Fegatella conica*. *Annals of Bot.*, vol. 9, p. 666.
Farmer.
'95d. Ueber Kerntheilung in Lilium-antheren, besonders in Bezug auf die Centrosomenfrage. *Flora*, vol. 80, p. 56.

Farmer and Moore.

'95. On the Essential Similarities existing between the Heterotype Divisions in Animals and Plants. *Anat. Anzeig.*, vol. 11, p. 71.

Farmer and Moore.

:03. New Investigations into the Reduction Phenomena of Animals and Plants. *Proc. Roy. Soc. London*, vol. 72, p. 104.

Farmer and Moore.

:05. On the Maiotic Phase (Reduction Division) in Animals and Plants. *Quart. Jour. Mic. Sci.*, vol. 48, p. 489.

Farmer, Moore, and Digby.

:03. On the Cytology of Apogamy and Apospory. *Proc. Roy. Soc. London*, vol. 71, p. 453.

Farmer and Williams.

'98. Contributions to our Knowledge of the Fucaceæ: their Life-history and Cytology. *Phil. Trans. Roy. Soc. London*, vol. 190, p. 623

Ferguson.

:04. Contributions to the Knowledge of the Life History of Pinus with Special Reference to Sporogenesis, the Development of the Gametophytes and Fertilization. *Proc. Washington Acad. Sci.*, vol. 6, p. 1.

Giltay.

'93. Ueber den directen Einfluss des Pollen auf Frucht und Samenbildung. *Jahrb. f. wiss. Bot.*, vol. 25, p. 489.

Grégoire.

'99. Les cinèses polliniques chez les Liliacées. *La Cellule*, vol. 16, p. 235.

Grégoire.

:04. La reduction numérique des chromosomes et les cinèses de maturation. *La Cellule*, vol. 21, p. 297.

Gregory.

:04. Spore Formation in Leptosporangiate Ferns. *Annals of Bot.*, vol. 18, p. 445.

Guignard.

'84. Recherches sur la structure et la division du noyau cellulaire. *Ann. d. Sci. Nat., Bot.*, ser. 6, vol. 17, p. 5.

Guignard.

'85. Nouvelles recherches sur le noyau cellulaire, etc. *Ann. d. Sci. Nat., Bot.*, ser. 6, vol. 20, p. 310.

Guignard.

'89. Étude sur les phenomènes morphologique de la fécondation. *Bull. Soc. Bot. d. France*, vol. 36, p. 106.

Guignard.

'91. Nouvelles études sur la fécondation. *Ann. d. Sci. Nat., Bot.*, ser. 7, vol. 14, p. 163.

GUIGNARD.

'99a. Le développement du pollen et la réduction chromatique dans le *Naias major*. *Arch. d'Anat. Mic.*, vol. 2, p. 455.

GUIGNARD.

'99b. Sur les anthérozoïdes et la double copulation sexuelle chez les végétaux angiospermes. *Compt. Rend.*, vol. 128, p. 864.

GUIGNARD.

:01. La double fécondation dans le maïs. *Jour. Bot.*, vol. 15, p. 37.

HAECKER.

'98. Ueber vorbreitende Theilungsvorgänge bei Thieren und Pflanzen. *Verh. d. deut. zool. Gesellsch.*, vol. 8, p. 94.

HEGELMAIER.

'97. Zur Kenntniss der Polyembryonie von *Allium odorum*, L. *Bot. Zeit.*, vol. 55, p. 133.

ISHIKAWA.

'97. Die Entwickelung der Pollenkörner von *Allium fistulosum*, L., ein Beitrag zur Chromosomenreduktion im Pflanzenreiche. *Jour. Coll. Sci. Imp. Univ. Tokyo*, vol. 10, p. 193.

JUEL.

'98. Parthenogenesis bei *Antennaria alpina* (L.) R. Br. *Bot. Centralb.*, vol. 74, p. 369.

JUEL.

:00. Vergleichende Untersuchungen über typische und parthenogenetische Fortpflanzung bei der Gattung Antennaria. *Handl. Sven Vetensk. Akad.*, vol. 33.

JUEL.

:04. Die Tetradentheilung in der Samenanlage von Taraxacum. *Ark. f. Bot. K. Svenska Vetens. Akad.*, vol. 2, no. 4.

KOENICKE.

:04. Die neueren Arbeiten über die Chromosomenreduction im Pflanzenreich und daran anschliessende karyokinetische Probleme. *Bot. Zeit.*, vol. 62, p. 305.

LANG.

'98. On Apogamy and the Development of Sporangia upon Fern Prothalli. *Phil. Trans. Roy. Soc. London*, ser. B, vol. 190, p. 187.

LANG.

:01. On Apospory in *Anthoceros lævis*. *Annals of Bot.*, vol. 15, p. 503.

LLOYD.

:02. The Comparative Embryology of the Rubiaceæ. *Mem. Torrey Bot. Club*, vol. 8, p. 27.

LOTSY.

'99. *Balanophora globosa* Jungh. Eine wenigsten örtlich-verwittwete Pflanze. *Ann. Jar. Bot. Buiten.*, ser. 2, vol. 1, p. 174.

LOTSY.

:03. Parthenogenesis bei *Gnetum ula* Brogn. *Flora*, vol. 92, p. 397.

LOTSY.

:04. Die Wendung der Dyaden beim Reifung der Tiereier als Stütze für die Bivalenz der Chromosomen nach der numerischen Reduktion. *Flora*, vol. 93, p. 65.

LOTSY.

:05. Die x-Generation und die 2x-Generation. Eine Arbeitshypothese. *Biol. Centralb.*, vol. 25, p. 97.

LYON.

:04. The Evolution of Sex Organs in Plants. *Bot. Gaz.*, vol. 37, p. 280.

MCCLUNG.

:02. The Accessory Chromosome — Sex Determinant? *Biol. Bull.*, vol. 3, p. 43.

MCCLURE.

'92. Corn Crossing. *Ill. Agric. Exp. Sta. Bull.* 21.

MOENKHAUS.

:04. The Development of the Hybrids between *Fundulus heteroclitus* and *Menidia notata* with Especial Reference to the Behavior of the Maternal and Paternal Chromosomes. *Amer. Jour. Anat.*, vol. 3, p. 29.

MONTGOMERY.

:01. A Study of the Chromosomes of the Germ Cells of Metazoa. *Trans. Amer. Phil. Soc.*, vol. 20, p. 154.

MONTGOMERY.

:04. Some Observations and Considerations upon the Maturation Phenomena of the Germ Cells. *Biol. Bull.*, vol. 6, p. 137.

MOORE, A. C.

:03. The Mitoses in the Spore Mother-cell of Pallavicinia. *Bot. Gaz.*, vol. 36, p. 384.

MOTTIER.

'97. Beiträge zur Kenntniss der Kerntheilung in den Pollenmutterzellen einiger Dikotylen und Monokotylen. *Jahrb. f. wiss. Bot.*, vol. 30, p. 169.

MOTTIER.

:03. The Behavior of the Chromosomes in the Spore Mother-cells of Higher Plants and the Homology of the Pollen and Embryo-sac. Mother-cells. *Bot. Gaz.*, vol. 35, p. 250.

MURBECK.

:01a. Parthenogenetische Embryobildung in der Gattung Alchemilla. *Lunds. Univ. Arsskrift*, vol. 36.

MURBECK.

:01b. Ueber das Verhalten des Pollenschlauches bei *Alchemilla arvensis* (L.) Scop. und das Wesen der Chalozogamie. *Lunds. Univ Arsskrift*, vol. 36.

Murbeck.

:02. Ueber Anomalien im Baue des Nucellus und des Embryosackes bei parthenogenetischen Arten der Gattung Alchemilla. *Lunds. Univ. Arsskrift*, vol. 38.

Murbeck.

:04. Parthenogenese bei den Gattungen Taraxacum und Hieracium. *Botan. Not.*, 1904, p. 285.

Nathansohn.

:00. Ueber Parthenogenesis bei Marsilia und ihre Abhängigkeit von der Temperatur. *Ber. d. deut. bot. Gesellsch.*, vol. 18, p. 99.

Nawaschin.

'98. Resultate einer Revision der Befruchtungsvorgänge bei *Lilium martagon* und *Fritillaria tenella*. *Bull. Acad. Imp. Sci. St. Petersb.*, vol. 9, p. 377.

Ostenfeld.

:04a. Zur Kenntniss der Apogamie in der Gattung Hieracium. *Ber. d. deut. bot. Gesellsch.*, vol. 22, p. 376.

Ostenfeld.

:04b. Weitere Beiträge zur Kenntniss der Fruchtentwicklung bei der Gattung Hieracium. *Ber. d. deut. bot. Gesellsch.*, vol. 22, p. 537.

Overton, E.

'93a. Ueber die Reduction der Chromosomen in den Kernen der Pflanzen. *Vierteljahrssch. d. naturf. Gesellsch. Zurich*, vol. 38.

Overton, E.

'93b. On the Reduction of the Chromosomes in the Nuclei of Plants. *Annals of Bot.*, vol. 7, p. 139.

Overton, J. B.

:02. Parthenogenesis in *Thalictrum purpurascens*. *Bot. Gaz.*, vol. 33, p. 363.

Overton, J. B.

:04. Ueber Parthenogenesis bei *Thalictrum purpurascens*. *Ber. d. deut. bot. Gesellsch.*, vol. 22, p. 274.

Pringsheim.

'76. Ueber vegetative Sprossung der Moosfrüchte. *Monatsber. d. k. Akad. d. Wiss. Berlin*, 1876, p. 425.

Raunkiaer.

:03. Kimdannelse uden Befrugtning hos Mælkebötte (Taraxacum). *Bot. Tidsskr.*, vol. 25, p. 109.

Robertson.

:04. Studies on the Morphology of *Torreya californica* Torrey. II. The Sexual Organs and Fertilization. *New Phytologist*, vol. 3, p. 205.

Rosenberg.

:03a. Das Verhalten der Chromosomen in einer hybriden Pflanze. *Ber. d. deut. bot. Gesellsch.*, vol. 21, p. 110.

ROSENBERG.
:03b. Ueber die Befruchtung von *Plasmopara alpina* (Johans.). *Bihang til K. Svenska Vet.-Akad. Hand.*, vol. 28, Afd. 3, No. 10.

ROSENBERG.
:04a. Ueber die Tetradenteilung eines Drosera-bastardes. *Ber. d. deut. bot. Gesellsch.*, vol. 22, p. 47.

ROSENBERG.
:04b. Ueber die Reduktionsteilung in Drosera. *Meddel. Stock. Hogs. Bot. Inst.*, 1904.

ROSENBERG.
:05. Zur Kenntniss der Reduktionsteilung in Pflanzen. *Bot. Notis.*, part 1, 1905.

SADEBECK.
'79. Schenk's Handbuch der Botanik, Breslau 1897. [An Account of Apogamy in Ferns]. Vol. 1, p. 231.

SARGANT.
'96. The Formation of the Sexual Nuclei in *Lilium martagon*. I. Oögenesis. *Annals of Bot.*, vol. 10, p. 445.

SARGANT.
'97. The Formation of Sexual Nuclei in *Lilium martagon*. II. Spermatogenesis. *Annals of Bot.*, vol. 11, p. 187.

SCHAFFNER.
'97. The Division of the Macrospore Nucleus (of *Lilium philadelphicum*). *Bot. Gaz.*, vol. 23, p. 430.

SCHOENFELD.
:01. La spermatogénèse chez le taureau et chez les mammifères en général. *Arch. d. Biol.*, vol. 18, p. 1.

SCHREINER AND SCHREINER.
:04. Die Reifungsteilung bei den Wirbeltieren. Ein Beitrag zur Frage nach der Chromatinreduktion. *Anat. Anz.*, vol. 24, p. 561.

SHAW.
'97. Parthenogenesis in Marsilia. *Bot. Gaz.*, vol. 24, p. 114.

STAHL.
'76. Ueber künstlich hervorgerufene Protonemabildung an dem Sporogonium der Laubmoose. *Bot. Zeit.*, vol. 34, p. 689.

STRASBURGER.
'84. Neuere Untersuchungen über den Befruchtungsvorgang bei den Phanerogamen als Grundlage für eine Theorie der Zeugung. Jena, 1884.

STRASBURGER.
'88. Ueber Kern- und Zelltheilung in Pflanzenreiche nebst einem Anhang über Befruchtung. *Hist. Beitr.*, Heft 1. Jena, 1888.

STRASBURGER.
'94a. The Periodic Reduction of the Number of Chromosomes in the Life-history of Living Organisms. *Annals of Bot.*, vol. 8, p. 281.

STRASBURGER.
'94b. Ueber periodische Reduktion der Chromosomenzahl in Entwicklungsgang der Organismen. *Biol. Centralb.*, vol. 14, pp. 817 and 849.

STRASBURGER.
'95. Karyokinetische Probleme. *Jahrb. f. wiss. Bot.*, vol. 28, p. 151.

STRASBURGER.
'97a. Kerntheilung und Befruchtung bei Fucus. *Jahrb. f. wiss. Bot.*, vol. 30, p. 351.

STRASBURGER.
'97b. Ueber Cytoplasmastrukturen, Kern- und Zelltheilung. *Jahrb. f. wiss. Bot.*, vol. 30, p. 375.

STRASBURGER.
'97c. Ueber Befruchtung. *Jahrb. f. wiss. Bot.*, vol. 30, p. 406.

STRASBURGER.
.00a. Ueber Reduktionstheilung, Spindelbildung, Centrosomen und Cilienbildner im Pflanzenreich. *Hist. Beitr.*, Heft 6. Jena, 1900.

STRASBURGER.
:00b. Einige Bemerkungen zur Frage nach der doppelten Befruchtung bei den Angiospermen. *Bot. Zeit.*, vol. 58, p. 293.

STRASBURGER.
:01. Ueber Befruchtung. *Bot. Zeit.*, vol. 59, p. 353.

STRASBURGER.
:04a. Anlage des Embryosackes und Prothalliumbildung bei der Eibe nebst auschliessenden Erörterungen. *Fest. z. 70th Geburtstag Haeckel.*

STRASBURGER.
:04b. Ueber Reduktionsteilung. *Sitzber. Akad. Berlin.* vol. 18, p. 587.

STRASBURGER.
:04c. Die Apogamie der Eualchemillen und allgemeine Gesichtspunkte die sich aus ihr ergeben. *Jahrb. f. wiss. Bot.*, vol. 41, p. 88.

STRASBURGER AND MOTTIER.
'97. Ueber den zweiten Theilungsschritt in Pollenmutterzellen. *Ber. d. deut. bot. Gesellsch.*, vol. 15, p. 327.

SUTTON.
:02. On the Morphology of the Chromosome Group in *Brachystola magna*. *Biol. Bull.*, vol. 4, p. 24.

SUTTON.
:03. The Chromosomes in Heredity. *Biol. Bull.*, vol. 4, p. 231.

TRETJAKOW.
'95. Die Betheiligung der Antipoden in Fällen der Polyembryonie bei *Allium odorum* L. *Ber. d. deut. bot. Gesellsch.*, vol. 13, p. 13.

TREUB.
'98. L'organe femelle et l'apogamie du *Belanophora elongata* Bl. *Ann. Jard. Bot. Buiten.*, vol. 15, p. 1.

TREUB.
:**02**. L'organe femelle et l'embryogénèse dans le *Ficus hirta* Vahl. *Ann. Jard. Bot. Buiten.*, ser. 2, vol. 3, p. 124.

TROW.
:**04**. On Fertilization in the Saprolegnieæ. *Annals of Bot.*, vol. 18, p. 541.

WEBBER.
:**00**. Xenia, or the Immediate Effect of Pollen in Maize. *U. S. Dept. Agric., Div. Veg. Path. Phys., Bull. 22.*

WILLIAMS.
:**04a**. Studies in the Dictyotaceæ. I. The Cytology of the Tetrasporangium and the Germinating Tetraspore. *Annals of Bot.*, vol. 18, p. 141.

WILLIAMS.
:**04b**. Studies in the Dictyotaceæ. II. The Cytology of the Gametophyte Generation. *Annals of Bot.*, vol. 18, p. 183.

WILSON.
:**00**. The Cell in Development and Inheritance. New York, 1900.

WINIWARTER.
:**00**. Recherches sur l'ovogénèse et l'organogénèse de l'ovaire des mammifères (lapin et homme). *Arch. d. Biol.*, vol. 17, p. 33.

WINKLER.
:**01**. Ueber Merogonie und Befruchtung. *Jahrb. f. wiss. Bot.*, vol. 36, p. 753.

WINKLER.
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WOLFE.
:**04**. Cytological Studies on Nemalion. *Annals of Bot.*, vol. 18, p. 607.

NOTES AND LITERATURE.

NATURE STUDY.

Nature Study.[1]—Two little text books on nature study, designed for use in the lower grammar school grades, give evidence of the progress which has been made during the last decade in laying the foundation for the teaching of the natural sciences. Too often in our public and private schools a teacher is expected to give her pupils "nature work," whether she herself is interested in the subject or trained for it. To such, if they have the gift of teaching, these books should prove helpful. Dr. Overton's in particular cannot fail to be stimulating to both teacher and pupil. It contains a series of thirty-two lessons on various simple phenomena of plant and insect life. Carter's *Nature Study with Common Things* is intended especially for city schools. It contains seventeen lessons on material taken exclusively from plant life, either the fruit or that part of the plant in which nutriment is stored. In the hands of an unskilful teacher this course could easily become a burden to the young pupil, inasmuch as it is limited to a field usually uninteresting to children. The following quotation from Dr. Overton's preface brings out one point frequently overlooked in a discussion of nature study; the italics are our own. "The object of nature study," says Dr. Overton, "is not so much to get present knowledge as to develop the power *and love* of observation by which knowledge may be gained in after life."

R. H.

[1] Overton, Frank. Assisted by Mary E. Hill. *Nature Study. A Pupil's Textbook.* New York, American Book Company, 1905. 142 pp., illus.

Carter, M. H. *Nature Study with Common Things. An Elementary Laboratory Manual.* New York, American Book Company, 1904. 150 pp., illus.

ZOÖLOGY.

Wasps Social and Solitary.[1] — Rarely has such a fascinating book as this on a given subject of natural history been presented to the lovers of nature studies. So clearly and charmingly written, it is a work from which all can derive pleasure and instruction. The amount of time and patience required to obtain a knowledge of the life habits of the various species can only be appreciated by one who has attempted to work out a few species bearing indirectly on another order of insects.

The varied habits of the wasps, from earth-diggers to wood-borers, and from masons to paper-makers, give one every opportunity of coming in contact with some of them during the many summer rambles, and often to observe them under the most favorable circumstances. Their methods of paralyzing other insects and spiders which they transport to their nests as food for their larvæ, suggests both surgical and engineering skill; equally interesting is the fact that each species selects certain kinds of food for its progeny; one captures spiders only, another the larvæ of Lepidoptera, a third flies, and others beetles or bugs. "So strong and deeply seated is the preference that no fly-robber ever takes spiders, nor will the ravisher of the spiders change to beetles or bugs."

The activities of the wasp are arranged under two groups: — "Instincts and Acts of Intelligence, it being understood that these classes pass by insensible stages into each other." Under the first are included stinging, the particular methods of attacking and paralyzing the prey, selecting the proper food, mode of carrying booty, the general style of nest, spinning of cocoons, etc. To distinguish acts of intelligence requires a familiarity with the normal conditions of the insect. Such modifications of instinct as the adaptation of the mud-daubers (Pelopæus) to the rafters and chimneys of buildings, the Trypoxylon taking advantage of the straws on the face of a stack that had been cut off smoothly, the hanging of spiders in a plant to avoid the attacks of ants while searching for a nesting-place, the occasional occupation by a queen Polistes of the previous year's comb instead of building a new one, the almost universal habit of Bembex of closing the openings to their burrows when leaving, and

[1] Peckham, George W., and Elizabeth G. *Wasps Social and Solitary.* With an introduction by John Burroughs. Boston and New York, Houghton, Mifflin & Co., 1905. 12mo, xv + 311 pp., illus.

of Pompilus of enlarging its nest to accommodate an unusually large spider, and of Ammophiles in seizing a small pebble in its mandible and pounding down the earth over the opening to its nest, would all come under the second group.

In summing up the chapter on the instinct and intelligence of wasps, the authors who have so entertainingly presented the facts, leave it largely to the reader "to determine whether the wasps are wiser than they seem or seem wiser than they are."

C. W. J.

Trouessarts' Catalogus Mammalium, Supplement.[1] — The great activity of the last few years in discovering and describing new species of mammals, living and fossil, has necessitated the preparation of a "quinquennial supplement" to include changes and additions made since the publication of the 1897 catalogue. The first three fascicles of this supplement list the known living and fossil Primates, Prosimiæ, Chiroptera, Insectivora, Carnivora (Fasc. 1); the Rodentia (Fasc. 2); the Tillodontia, Ungulata, and Sirenia (Fasc. 3). The fourth fascicle will conclude the work and will contain an index. In the preface the author states that the present supplement is intended to summarize the state of our knowledge on this subject to date of January 1, 1903, though in fascicle 3 certain new genera and species described in 1904, are included without explanation, *e. g.*, Nesohippus Amegh. (p. 635). In addition to listing the new forms, all the species noted in the edition of 1897–99 are given in their proper place, each with its serial number, but instead of the list of references following, there is added simply a number referring to the full quotations for the species given in the former list, in cases where no change has been made. A new feature introduced in the present supplement is the citation of the full reference in case of generic and subgeneric names. Footnotes and explanatory remarks are in French, not in Latin as in the previous edition.

In general the compiler has made no attempt at revisionary work so far as concerns specific determinations, but some care has been used in replacing unavailable generic and subgeneric names with new or later ones. Thus, in including Matschie's revision of the anthropoid apes, Trouessart does not repeat that author's error of

[1] Trouessart, E. L. *Catalogus Mammalium tam Viventium quam Fossilium. Quinquennale Supplementum, Anno 1904.* Berlin, R. Friedländer & Sohn, 1904–1905. Fasc. 1–3, 8vo, iv + 752 pp. 12 Mk. per fasc.

adopting Troglodytes as the generic name of the chimpanzee, but unfortunately he overlooks the earliest available name, Pan, recently revived by Palmer. Also, the authority for the specific name of *Gorilla gorilla* should be Savage, not Wyman. Midas should not have been used as a name for a mammalian genus, as it is preoccupied among the Lepidoptera. The following new subgeneric names are proposed for Primates: Pogonocebus to replace Diadema, Leptocebus for Semnocebus, Maimon for Mormon, Promioclænus for Mioclænus. Palmer has recently shown, however, that Mandril of Voigt (1831) is available for Mormon, while the same author in 1903 proposed the subgeneric term Lophocebus to replace subgenus Semnocebus.

In the determination of subfamilies, genera, and subgenera, Trouessart frequently follows his own preference, and not always, it would seem, to best advantage. Thus Pipistrellus and Lasionycteris are regarded as subgenera of Vespertilio, and Dasypterus is placed as a subgenus of Lasiurus, while two such closely allied forms as Nycticeius and Rhogeëssa are nevertheless accorded their generic rank. Artibeus is made to include Uroderma and Dermanura as subgenera. Other instances might be multiplied.

Additional new generic and subgeneric names proposed are: Jentinkia to replace Wagneria, Aymardia for Cynodon, Pagophoca for subgenus Pagophilus, Orthægocerus a new subgenus of Capra. The new family name Cœndidæ is proposed instead of Erithizontidæ for the New World porcupines.

Trouessart has made a laudable attempt to sort out so far as may be the numerous new species of Muridæ described in 1900 from Chile by Philippi, mostly under the generic name Mus. One of these names, "*Mus nemoralis*," thought by Trouessart to be an Oxymycterus, is preoccupied by *Mus nemoralis* Blyth, though this seems to have escaped the notice of the compiler. Philippi's "*Cervus brachyceros*" is similarly preoccupied and is renamed by Trouessart, *Odocoileus philippii*.

The questionable practice of amending names leads the compiler to change Tayassu to Tayassus since, he states, barbaric names should be latinized. Nevertheless he rejects Dugong in favor of the retal Halicore on the ground that the former is a barbaric name. It is a pity, however, that it is not possible to exclude such abnormalities as Guilielmofloweria or Carolozittelidæ!

Apparently Miller and Rehn's list of North American land mammals published in 1901 (*Proc. Boston Soc. Nat. Hist.*, vol. 30) was

unknown to the compiler. Comparison with this might have been of considerable value and would have prevented, for example, the omission of *Fiber osoyoosensis* Lord, 1863.

Considering the editorial difficulties presented by a work of this nature, typographical errors are few. Several cases occur, however, in which the prefix denoting fossil species only is inadvertently applied in connection with living forms, *e. g.*, *Lama vicugna* and *Trichechus manatus*. The specific name of the capybara is misspelled four times on p. 529.

The Catalogus gives evidence of laborious and painstaking work throughout, and is indispensable to all working mammalogists. For this reason, however, it is to be regretted that the price (12 Marks per fascicle) is such as to place it beyond the means of many who need it.

G. M. A.

(No. 463 was issued July 13, 1905.)

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INTERRELATIONSHIPS OF THE SPOROZOA.

HOWARD CRAWLEY.

Other things being equal, it is perhaps an easier task to determine the interrelationships of a group of parasites than those of a series of free-living forms. Once the parasitic habit is acquired, development is confined within narrow limits. Two definite lines are followed. These are: morphological degradation, and complication of the life history combined with increased fecundity. It is perfectly evident why this should be. Individually, the parasite is at once relieved of two of the great problems of animal existence. These are: the obtaining of food and the avoidance of serving as food for some other animal. The parasite has no enemies and abundant food surrounds it on all sides. As a result, various parts necessary to a free-living animal are lost. These are: the organs concerned with the capture and digestion of food, and those which serve as protection against the attacks of enemies. On the other hand, the new mode of life involves new needs, and the organism responds by the production of new organs. Such are: hooks, providing for the maintenance of a fixed position, and, in many cases, beaks or rostra which enable their possessors to bore through the tissues of the host.

Finally, a parasite acquires the ability to resist being digested. This appears in some cases to result from the formation of a differentiated external layer, but in general it is to be credited to some property of the living protoplasm. It is, necessarily, a property possessed by all organisms which live within others, and hence has no taxonomic value.

But if the existence of the individual is rendered easier, that of the species is menaced by a danger not experienced by free-living forms. With these, birth, growth, and reproduction all take place in free nature. For the most part, the eggs and young are left to shift for themselves, but the dangers which they encounter, are much the same as those which threaten the adults. The greater mortality during these stages is primarily due to their greater helplessness. But it is far different in the case of parasites. For these the course must, so to speak, consist of a series of leaps. A given host, at best, eventually dies and its death involves that of its parasites, as individuals. Hence the eggs or spores must be transferred to another host or else the species will cease to exist. Parasites are so abundant, and so thoroughly well established that we are prone to overlook what a radical departure this is from the ordinary scheme of animal life. The elements destined to tide the species over this critical period reach the exterior in one of several ways. The more usual are either by the death of the host, or by being carried out with its fæces. Ordinarily animals do not eat either their own dead or their own fæces, whence the only chance the germ has is to become attached to the food and so swallowed. Accordingly, as a general rule, parasites are common in social and uncommon in solitary animals. The termites, which do eat their fæces, invariably have their intestines literally packed with the curious Trichonymphidæ.

The response of the species to this acquired peril is two-fold. Complications are introduced into the life history. These are of such a character as to increase the probability of obtaining lodgment within the appropriate host. This is the most striking feature displayed by parasites. The other response is the acquisition of great fecundity. Great stress is always laid upon this, yet it is after all doubtful if parasites, taken as a whole, do

actually exceed other less specialized forms of life in their reproductive powers. Nevertheless the germs are produced in such numbers that if one in many thousands survive, the perpetuation of the line is assured.

Examples in support of the statements given above are numerous. Certain animals, particularly the small Nematodes, live indifferently either in the outside world or else upon or within higher forms. Such may be regarded as upon the threshold of the parasitic life. A second step is taken by those Flagellates which inhabit the recta of frogs and salamanders. These animals are morphologically like their free-living congeners nor is their life history known to be more complicated. But turning to the flat-worms we find the parasitic habit in its most confirmed aspect. This phylum, moreover, furnishes us with a series of stages from typical free-living forms to typical parasites. It is divided into three classes: the Turbellaria, the Trematoda, and the Cestoda. The first class consists mainly of free-living animals, and is characterized by an alimentary canal and a ciliated epidermis. The Trematoda retain the intestine, but have lost the cilia. The Cestodes go farther, and losing all trace of an alimentary canal, absorb their nutriment through the epidermis. There is thus a progressive morphological degradation.

But along with this change in the individual, there is a striking change in the life history. In the free-living Turbellaria and the ectoparasitic Trematodes, development is direct. That is, the eggs produce young which grow to be adults without metamorphosis. On the other hand, the endoparasitic Trematodes and the Cestodes bear off the palm for a complicated life history. The organisms hatched from the eggs are wholly unlike the adults, and there is always at least one metamorphosis. In addition, change of host is invariable. Thus, the liver fluke of the sheep spends a part of its existence in a water snail. Indeed, from a purely utilitarian standpoint, these animals appear to have overshot the mark, and their ontogenetic development defies a rational explanation. The desired end could apparently have been reached quite as certainly by less devious methods. But while we cannot explain the *raison d'être* for such processes, it is evident that they indicate a confirmed parasitism. These

animals are without doubt the descendants of a long line of parasitic ancestors and they probably represent the limit to which the habit can go.

We are thus furnished with two criteria enabling us to gauge the modifications induced by this mode of life. That is, given two allied groups of parasites, that possessing the more degraded organization and more complex life history is to be considered as the less primitive. A third criterion is furnished by the part of the host chosen for a habitat. Without doubt, the original gateway was the mouth or the rectum. Thus the less modified parasites are inhabitants of the alimentary canal. Examples are such animals as *Amœba blattæ* and the various Flagellates mentioned above, which dwell in the recta of frogs and salamanders. Access to the lungs and liver is also easy, although some of the parasites of the latter organ reach their chosen place by an indirect path. In the case of the inhabitants of the sexual organs, muscles, and brain, the infection comes in most cases by way of the intestine. There is, however, no direct road and the parasite must bore its way through the tissues of the host. These parasites are generally of the most modified types. On the contrary, the greatly modified Cestodes, at least in one of their hosts, live in the alimentary canal. This criterion, then, needs to be used with much more caution than the other two.

Having obtained certain criteria, I shall endeavor to apply them to the matter in hand, as indicated by the title of my communication. The Sporozoa stand alone. Their ancestors were in all probability Protozoan, but they branched off at so early a period that there remain absolutely no connecting links between them and any of the other classes of the Protozoa. There are two rival views regarding their origin. Minchin[1] aptly terms these the euglenoid and the amœboid hypotheses. The one regards the Flagellates, the latter the Rhizopods, as the ancestral forms. Bütschli has advocated the former, whereas Minchin pronounces in favor of the latter. To me, however, it appears that neither can be adopted without reserve. Each, by implication, assumes that all Sporozoa have had a common

[1] *A Treatise on Zoölogy*, edited by E. Ray Lankester, Chapter 1, Section K.

origin, which, for reasons that I shall give, does not appear to be the case.

The class itself falls readily into two subclasses: the Telosporidia and the Neosporidia. In the former, arrived at a certain stage of its existence, the individual divides into reproductive elements, the spores, and ceases to exist as an individual. In the latter, vegetative growth and spore formation proceed hand in hand. Further, the Telosporidia display sexual differentiation of fully as definite a character as the mammals, while nothing of the sort has as yet been described for the Neosporidia.

The division into lesser groups is as follows: —

TELOSPORIDIA.

Order 1, *Gregarinida.*
  Suborder 1, Schizogregarinæ.
  Suborder 2, Eugregarinæ.
    Tribe 1, Acephalina [Monocystidea].
    Tribe 2, Cephalina [Polycystidea].
Order 2, *Coccidia.*
Order 3, *Hæmosporidia.*
  Suborder 1, Hæmosporea.
  Suborder 2, Acystosporea.

NEOSPORIDIA.

Order 1, *Myxosporidia.*
  Suborder 1, Phænocystes.
  Suborder 2, Cryptocystes.
Order 2, *Sarcosporidia.*
Order 3, *Haplosporidia.*

This is Minchin's classification, excepting the fact that I have included the Haplosporidia. Doflein[1] rates the Coccidia and Hæmosporidia as suborders, the two making up the order Coccidiomorpha. This is probably an improvement.

[1] *Archiv für Protistenkunde*, vol. 1, 1902.

Of all the Telosporidia, the Polycystidea stand highest in organization. Their name indicates the fact that they are divided into parts. The division is longitudinal and the parts, from before backward, are termed epimerite, protomerite, and deutomerite. The epimerite is an organ of attachment, comparable to the suckers of Trematodes and the hooks of Cestodes. It is peculiar to the Polycystidea and has evidently been evolved to meet the requirements of an intestinal life. The protomerite and deutomerite are the two "cysts" of the gregarine body. The latter is nearly always much the larger, and contains the nucleus.

From without inward, the ectosarc of a Polycystid gregarine shows epicyte, sarcocyte, and myocyte. The epicyte is a membrane of some formed substance. Its function is probably to guard against the too rapid action of the fluids of the host's intestine. The sarcocyte in protoplasmic and an ingrowth from it forms the septum which separates the protomerite from the deutomerite. The myocyte is a muscular system of longitudinal and transverse fibers. By means of various contractions of these fibers gregarines are able to change shape and to display locomotor movements.

It is thus seen that as regards both form and anatomy the Polycystids are somewhat complicated animals. They are also exclusively intestinal parasites and there is neither change of hosts nor alternation of generations. If then our criteria be of any value, the Polycystid gregarines are the least modified of the Telosporidia and stand nearest to the stem from which the entire subclass originated. Assuming this as a working hypothesis, it remains to be seen if the remainder of the Telosporidia can be derived from them.

Gregarines develop from a minute protoplasmic body, known as a sporozoite. The sporozoite is piriform or vermiform. At the anterior end, the protoplasm is stiffened and forms the so called rostrum, by means of which the organism is able to work its way into an epithelial cell of the host's intestine. As a rule, penetration is only partial and the Polycystidea, with the exception of a single family (the Stenophoridæ), are never cell parasites. In its chosen place, the sporozoite grows to be an adult

gregarine, or trophozoite. In most cases, the attachment to the host epithelium is sooner or later lost and the gregarine takes up a free life in the intestine of its host. In some species the attachment is maintained until the animals are sexually mature, but the distinction is not important.

Although lacking in secondary sexual characters, the adult gregarines are male and female. We owe this knowledge to the recent brilliant work of Léger. At the proper period, two of opposite sex come together, conjugate, and form a cyst. Within the cyst, the male gregarine produces motile, tailed elements, the spermatozoids. The female gregarine produces rounded cells, the eggs. At maturity, the spermatozoids seek and fertilize the eggs. Each fertilized egg eventually produces a spore, the contents of which septate into eight sporozoites. Ordinarily, the cysts reach the exterior shortly after their formation, and sporulation takes place while the cyst is lying on the earth. It may, however, be completed with the cyst still in the host intestine, but auto-infection has never been described.

Eventually the cyst opens and the spores are set free. These, if they reach the intestine of another individual of the host species, dehisce and release the sporozoites. Otherwise their fate is doubtless death.

In the classification given above, the Gregarinida are ranked as an order. This order is divided into two suborders: the Schizogregarinæ and the Eugregarinæ. The former includes those animals originally termed the Amœbosporidia. They possess a fixed body form, but their anatomy is much simpler than that of the Eugregarinæ. There is an alternation of generations. So far, however, but four or five species are known, and this rarity appears to be actual and not merely the result of insufficient study. For the time being, it appears best to regard them merely as a small offshoot from the Eugregarinæ.

The Eugregarinæ are divided into tribes. In the more recent general works, these are named the Cephalina and the Acephalina. There does not seem, however, to be any good reason for abandoning the older terms Polycystidea and Monocystidea. Except for the interpolation of the Schizogregarines, this classification is the same as that which has been in vogue for many years.

Its implication is that the relationship between the Polycystidea and Monocystidea is very close. Relatively, this is true, yet there are considerable differences. For one thing, reproduction in the Monocystids is isogamous. The encysted trophozoites each break up into gametes, which are all alike. These gametes fuse in pairs to form the zygotes. It is assumed that in each zygote, one gamete has been derived from one trophozoite and the other from the other, but the point is necessarily almost impossible to demonstrate. Each zygote produces a spore.

In the second place, the Monocystidea are far simpler in organization than the Polycystidea. While some of them possess a definite body form, many do not. Moreover, as their name indicates, their bodies are never divided into two chambers, a result of the loss of the sarcocyte. It is on this same account, in all probability, that they are polymorphic. Now, throughout the Polycystidea a perfect series can be established based on the development of the sarcocyte. In some it is always thick and continuous all over the body. In others it is but feebly developed, while in a certain number the septum disappears, and these species simulate the Monocystidea. The element is obviously in a transitional state, and since we are dealing with parasites, we are warranted in supposing it is disappearing.

Considering next the life history, the Monocystids, like the Polycystids, develop from a sporozoite which is released in the intestine of the host. But whereas in the latter group the sporozoite never gets farther than the intestinal epithelium, in the former it penetrates the cœlome. Some Monocystids develop in the connective tissue surrounding the intestines of their hosts, whereas others go farther. Thus, in the Monocystids of the earthworm, the sporozoites gain the seminal vesicles before developing into gregarines.

We are thus furnished with certain data enabling us to determine which of these two groups is ancestral. The evidence awards this distinction to the Polycystidea. That furnished by the sarcocyte is very suggestive, and the Monocystidea, which lack it, are to be considered the derived group. The life history points in the same direction. It is to be assumed here, as it is in the case of most animals, that ontogeny recapitulates phy-

logeny. That is, the Monocystids have arisen from certain sporozoites, which have pushed their way entirely through the intestinal epithelium instead of remaining either attached to it or within it. Finding in this way a congenial environment, they have survived and eventually established a new group of animals.

It is thus possible to decide which of the two modes of reproduction displayed by these two groups is the more primitive. On *a priori* grounds, heterogamy can be derived from isogamy or isogamy from heterogamy. But, presumably, the more primitive group will display the more primitive mode of reproduction. Whence the conclusion appears justifiable that the lack of sexual differentiation in the Monocystidea is the result of a loss. This conclusion is supported by the fact that, in the other Telosporidia, the organisms are male and female.

The life history of a Coccidian begins in precisely the same way as that of a gregarine. A sporozoite, released in the lumen of the intestine, seeks and penetrates an epithelium cell. From this point, one of two courses may be followed. Easily satisfied, the sporozoite may settle down at once within the cell it has entered, and proceed to grow. Or else it may completely pass through the intestinal wall, and eventually come to rest within a cell of the liver, kidney, or testis. In either case, once established, the organism grows until it reaches a certain definitive size. Then, by a process termed schizogony, it divides into a number of merozoites. These seek fresh cells, which they invade. The schizogonous cycle, which may be repeated many times, occasionally produces the parasites in such numbers that the host is killed. But whether or not, at the end of a certain time, the merozoites develop into male and female cells. Each male cell produces a number of minute elements, the microgametes. Each female cell develops into a single egg, or macrogamete. At maturity, the mobile microgametes seek and fertilize the eggs. Immediately after fertilization, the egg lays down a protective covering and becomes an oöcyst.

The process differs from that in the Polycystidea in two respects. In these, the female trophozoite produces numerous eggs and fertilization takes place within the cyst. In the Coccidia, each female trophozoite metamorphoses into a single egg,

and encystment follows fertilization. The attempts to homologize these two methods are not wholly satisfactory, and do not shed much light on the relationship of the two groups. It may be observed, however, that wherein the Coccidia differ from the gregarines, they approach the conditions found in the highest animals.

Accordingly, in the attempt to derive the Coccidia from the gregarines, it is advisable to seek evidence other than that furnished by the reproductive processes. This is furnished by the life history and the habitat. The Coccidia display an alternation of generations and live within cells. These are both indicative of a greater specialization than is shown by the gregarines. We may imagine that in evolution certain sporozoites penetrated completely within the cells of the intestinal epithelium, and there remained and developed. Such a habit, once acquired, would speedily lead to morphological degradation. The Polycystidea may almost be said to lead a free life. They possess and exert the power to move from place to place. But the Coccidia, living within cells, add to the degradation which follows from a parasitic, that which results from a sedentary habit. Two influences are thus at work upon them, and they have become the most simply organized of all the Sporozoa. Their form is spherical or ellipsoidal, that taken by any non-living liquid when in a state of equilibrium. Anatomically, they are merely nucleated masses of cytoplasm, not even displaying differentiation into ectosarc and endosarc.

It then seems justifiable to derive the Coccidia from the Polycystidia, although perhaps indirectly, for reasons which I shall give. The fact that some inhabit the internal organs of the host presents no difficulty. In numbers, those infesting the intestinal epithelium are much in excess. These were doubtless first evolved. The intracellular habit once acquired, the organ-infesting Coccidia could easily have arisen from those living in the intestinal epithelium. The more venturesome sporozoites, by passing entirely through the intestinal wall, finally gained one of the internal organs. The pabulum furnished by a kidney or testis cell being satisfactory, the line was established.

The last group of the Telosporidia is the Hæmosporidia.

This order is, in some respects, the best studied of all the Sporozoa, since it numbers amongst its members the parasites of malaria and yellow fever. In the acquisition of two hosts, it reaches a higher degree of specialization than the Coccidia, and extreme specialization is also indicated by the relative paucity in species. It is to be remembered, however, that from the biological side, the group is not so well known as either the Coccidia or the Gregarinida. Accordingly, generalizations valid to-day may need to be modified as our knowledge increases.

Two suborders have been established, the Hæmosporea and the Acystosporea. With the exception of one important feature, the life history of these two is the same. It is further essentially the same as that of the Coccidia.

As in the rest of the Telosporidia, the Hæmosporidian begins its career as a sporozoite. Set free in the blood of the host, this sporozoite attacks and enters a blood cell, preferably an erythrocyte. Here it grows into a trophozoite, which is amœboid in the Acystosporea and generally vermiform in the Hæmosporea. The trophozoite, growing at the expense of the blood cell, soon breaks up into a number of merozoites. By the disintegration of the blood cell, the merozoites fall into the blood stream. Forthwith they attack new blood cells and the process (schizogony) is repeated. The increase is therefore by geometrical ratio and as Minchin says: "It is evident that reproduction at this rate could only continue indefinitely in the *ichor* of an infinite host." Accordingly, at the end of a certain number of generations, the parasite provides for its future by the production of male and female elements.

So far the process is exactly parallel to that found in the Coccidia. In the Hæmosporidia, however, or rather in the Acystosporea, the male and female cells must be removed from the blood of the host to insure further development. This removal is effected by a blood-sucking insect (a mosquito) which takes the parasites into its alimentary canal. Here they mature, the male cells forming each a number of microgametes, the female cells each a single macrogamete or egg. The microgametes fertilize the macrogametes, which then metamorphose into elongated elements, the oökinetes. The oökinete pierces the

intestinal epithelium of the mosquito and comes to rest in the peri-intestinal tissue. There is first a period of growth, during which the element assumes a spherical form and becomes inclosed by a delicate wall. No actual cyst is developed. Eventually, the sporozoites are produced directly from the protoplasmic mass, the spore stage being omitted. Excepting for the fact that fertilization is postponed until after the removal of the parasite from the vertebrate host, that part of the Acystosporean life history which is passed in the mosquito corresponds exactly to that part of the Coccidian life history which is passed in the cyst.

The Acystosporea are parasitic in the blood of mammals and birds. Intermediate hosts are known in many cases, and they are generally assumed in the rest. The Hæmosporea, on the other hand, infest reptiles and batrachians. Intermediate hosts are not known,[1] nor can we readily believe that such forms are much preyed upon by Diptera. However greatly we may dread the mandibles of the mosquito, the Chelonia are probably indifferent to its attacks. Moreover, in the case of Lankesterella of the frog, it has been shown by Hintze[2] that sexual reproduction takes place in the blood, and that the motile zygotes so formed gain the epithelium of the intestine. Here they encyst, the cysts so formed eventually reaching the exterior by being carried out with the fæces of the host.

If the life history of Lankesterella may be taken as representative of that of the Hæmosporea, we find that the two suborders of the Hæmosporidia differ only in that the Acystosporea have acquired an intermediate host. While this is indicative of more extreme specialization, it is not difficult to imagine how it may have been brought about. The warm-blooded vertebrates have doubtless long been preyed upon by blood-sucking arthropods. The crucial point in the bringing about of this change of life on the part of the parasites was that some such bloodsucker would be unable to digest them. This would be merely a matter of chance. There was probably one time in their

[1] A case has, however, recently been described.

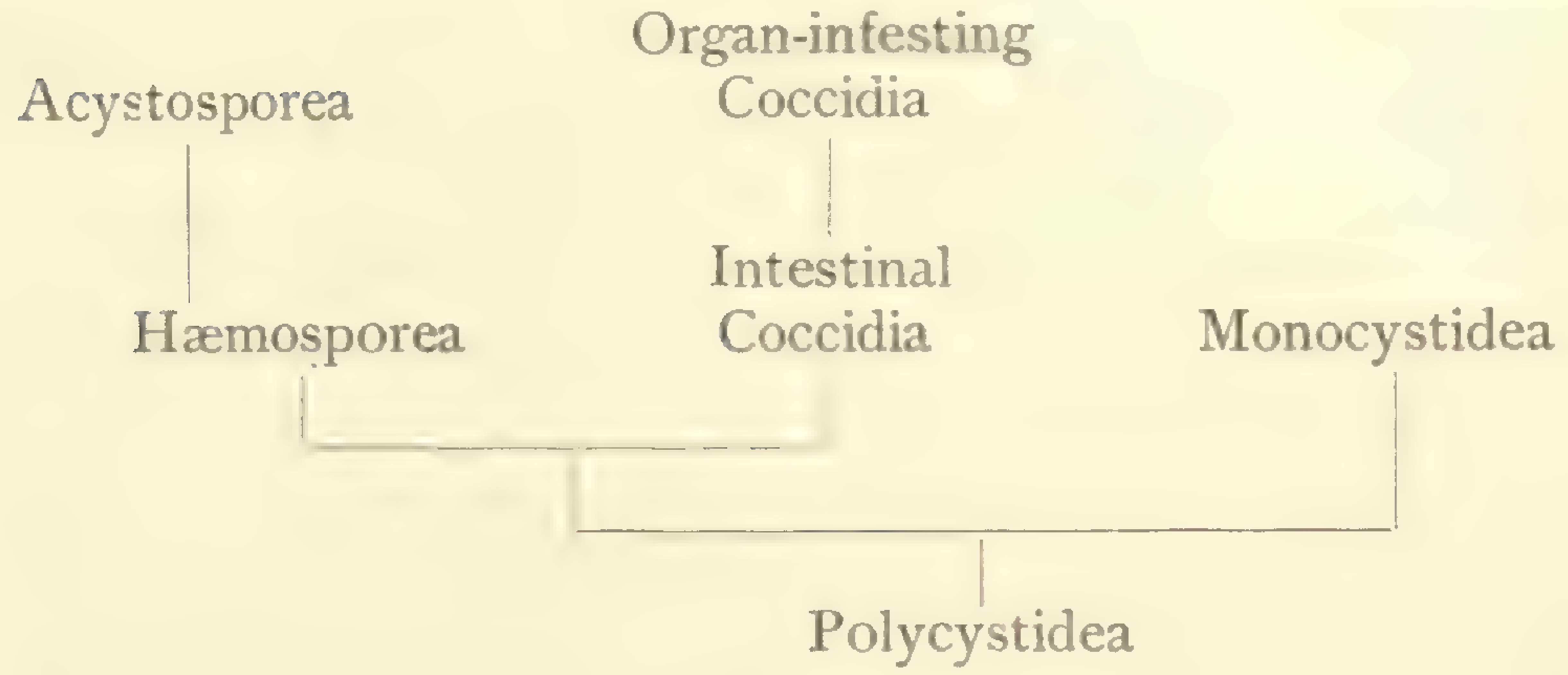
[2] *Zoöl. Jahrb., Abth. f. Anat.*, vol. 15, 1902, pt. 4, p. 693.

evolution when the Acystosporea could infect their vertebrate hosts in two ways, but the intestinal method is now lost. The acquisition of an intermediate host is obviously advantageous to the species, tending, as it does, to a wider distribution.

There are, however, anatomical differences between the Hæmosporea and the Acystosporea. The former, in the trophozoite stage, possess a definite body form, on which account they are often spoken of as Hæmogregarines. This definite form is due to the presence of a dense hyaline ectosarc, in which myocyte fibrillæ have been demonstrated. These animals, although typically cell parasites, indulge in frequent migrations in the blood plasma, and during such "free" phases, they display both contractile and locomotor movements. On the other hand, the trophozoites of the Acystosporea appear never to migrate. The blood cell originally attacked is abandoned only after the organism has divided by schizogony. No special anatomical differentiation appears to have been described, but the trophozoites undergo sluggish amœboid movements. Accordingly, as regards both the morphology and the life history, the Acystosporea are clearly the more specialized group. It next remains to relate the blood parasites with their closest relatives, the Coccidia.

As regards the life history, the parallelism is exact, except for the acquisition of an intermediate host in the Acystosporea. The sexual processes are practically identical. Morphologically, however, the Coccidia are practically on a par with the Acystosporea and considerably more degraded than the Hæmosporea. Comparing the Coccidia and the Hæmosporea, the former would, according to our criteria, be the derived group. But the favored habitat of the Coccidia is the epithelium of the intestine, and it seems as if this must have been occupied by Sporozoan parasites before invasion of the blood.

The view advanced by Minchin seems best to fit the case. This is that both Coccidia and Hæmosporidia have arisen from common ancestors. These ancestors in their turn I believe to have been derived from the Polycystidea, and my conception of the interrelationships of the Telosporidia is indicated by the following scheme: —



The habitat of the Polycystidea, the intestine of their hosts, has enabled them to lead a practically free life. Accordingly, they are the least modified of all Sporozoa, and have retained nearly as complex an organization as the Flagellates. They have given rise, on the one side, to the Monocystidea and on the other to the Coccidiomorpha. The former followed much the same lines as their immediate ancestors, but have undergone morphological degradation. The Coccidiomorpha became adapted to an intracellular life, and separated into two groups. In one of these, the inert Coccidia, morphological degradation has been carried to its extreme. The greater anatomical complexity of the Hæmosporea is to be credited to their habitat. The liquid blood offers a radically different environment from the motionless epithelium. In consequence, the power to move, possessed at the outset by the Hæmosporea as an inheritance from their Polycystid ancestors, has not been lost. Thus these animals possess the characteristic Telosporidian organ of movement, a myocyte. The Acystosporidia, further evolved, have apparently lost the ability to move from place to place. Their inertness, although comparable to that of the Coccidia, has been independently acquired. Finally, in their ability to display amœboid movements, they have not sunk quite so low.

Mesnil[1] considers the ancestral Telosporidian to be a Monocystid intestinal gregarine. Minchin derives the group from a hypothetical intracellular form. In both cases this ancestor is supposed to have given rise to existing gregarines on the one hand, and to the Coccidiomorpha on the other. To my mind,

[1] *Vol. Jubil. Soc. de Biol.*, Paris, 1899.

these hypotheses are open to objection in that they are based almost exclusively on the reproductive phenomena. They both involve the evolution of a more from a less complexly organized parasite. I have endeavored to show that this is contrary to what experience teaches us to expect. In our classification of the Metazoa morphology is given first place and it should not be neglected in a consideration of the Protozoa. The remarkable character of the reproductive phenomena displayed by the Sporozoa has, I think, given them an undue importance. The form of the adult animals has, in any attempt at a classification, at least equal value.

We have now to consider the Neosporidia. This subclass is but poorly known. As shown above, it consists of three orders, the Myxosporidia, the Sarcosporidia, and the Haplosporidia. The Myxosporidia are characterized by their peculiar spores, which bear a close resemblance to the stinging cells of cœlenterates. The spore consists of a bivalved shell, inclosing the sporoplasm and the polar capsules. The polar capsules, of which there may be from one to four, are tightly coiled filaments which occupy vacuities in the spore substance. Acted upon by the digestive juices of the host, the spore shell opens and the filaments are everted. By means of these filaments the spore is held attached to the intestinal epithelium of the host, and the sporoplasm escapes as a minute amœbula. Freed on the surface of a host cell, it works its way within and comes to rest. The nucleus presently divides, then the cytoplasm, and each spore thus produces a number of bodies which are at least the analogues of the Coccidian merozoites. They scatter throughout the host and each gives origin to a trophozoite. The trophozoite grows larger, becomes multinucleate and soon begins to form spores. These, eventually reaching the exterior, are fitted to infect new hosts.

The above outline of the life history is that given by Doflein. It is to be observed that there is no sexual process. Doflein, however, considers it possible that either the spores themselves may conjugate very shortly after their escape from the spore shell, or else that this process may take place between the young trophozoites. This he advances merely as a surmise, there being no observational evidence.

The young trophozoite may follow one of several lines of development. These lines diverge considerably. The nature of the forms so produced is indicated in the following table, which is taken from Doflein: —

Group I. Free-living forms.
Group II. Sedentary forms.
1. Inclosed in cysts.
2. In the state of "diffuse infiltration."
3. Cell parasites.

Group I contains the most highly organized of the Myxosporidia. Its members lead a free life in the gall bladder, urinary bladder, or kidney tubules of their hosts. They display differentiation into ectosarc and endosarc. The latter is essentially like that of other Sporozoa. The former is a clear granular layer. It is the seat of motion and gives origin to the pseudopodia. A myocyte does not appear to have been described. Throughout these animals resemble the Rhizopoda.

Group II is doubtless an offshoot from Group I, with the exception of the cell parasites. The encysted forms are those which come to rest at some point within the host's body. The part thus attacked reacts by the formation of a wall around the parasite, which is thereupon prevented from extending its explorations. "Diffuse infiltration" results when the parasite spreads out through a considerable region of the host's tissues. In such cases no cyst is formed. Eventually, these two kinds of trophozoites die as trophozoites, but leave the tissues which they had occupied, filled with spores.

The forms hitherto considered are mostly animals of considerable size, while the cell parasites, which belong to the suborder Cryptocystes, are amongst the smallest of the Sporozoa. The mode of life is, however, much the same. It is to this group that belongs the destructive *Nosema* (*Glugea*) *bombycis*, the cause of the silk-worm disease.

In no Myxosporidian is an intermediate host known, and infection is apparently always the result of chance. In those forms which live in such places as the gall or urinary bladder, the

spores are assumed to reach the exterior with the evacuations of the host. For the tissue-infesting species, however, there are no natural channels. Where the parts attached are superficial, it is conceivable that the tumors which so frequently occur in Myxosporidian infection may break to the exterior. In this way the spores would be set free. But in deep-seated infections the conclusion seems inevitable that the death of the host is necessary. This conclusion is supported by the fact that extensive infections are generally fatal.

The Myxosporidia attack cold-blooded vertebrates and arthropods. The Sarcosporidia confine their attentions to birds and mammals. They are very abundant in the visceral muscles of sheep and swine. While their spores differ from those of the Myxosporidia, the animals themselves are morphologically a good deal like those members of the last-named group which live in cysts or in the state of diffuse infiltration. Additional data regarding them are a crying need and at present all that can be said is that they have probably evolved from Myxosporidian-like ancestors. The Haplosporidia may be dismissed at once. Our knowledge is too scanty to warrant any generalizations.

It is possible, however, to compare the Neosporidia with the Telosporidia. Taking the free-living Myxosporidia on the one hand, and the Polycystidea on the other, we fail to detect any points of similarity. The habitats, life histories, and reproductive processes are wholly different. There is no morphological likeness in any of the stages, from spore to trophozoite. In a few cases, gregarines are almost amœboid and can protrude pseudopodia. The Monocystids, also, are cœlomic parasites and some species live in the organic cavities of their hosts. But this appears to be the sum total of the evidence indicative of any connection between the two groups. It is palpably insufficient.

Unless, then, future discoveries of a fundamental nature shall be made, there seems ample warrant for the view expressed by Mesnil and Doflein. This is that the Telosporidia and Neosporidia are not genetically connected. Accordingly, at least for the present, we should use the term Sporozoa merely as a convenient cloak. It serves to cover certain Protozoa which cannot be placed in any of the other Protozoan classes. It is not so long

since the so called Vermes subserved a like function among the invertebrates. Happily, in this case, confusion has been reduced to order and we who are interested in the Protozoa may hope that history will repeat itself.

WYNCOTE, PA.

CONTRIBUTION TO OUR KNOWLEDGE OF THE MYXINOIDS.[1]

JULIA WORTHINGTON.

Introduction.

Ever since Johannes Müller introduced the Myxinoids to the scientific world, interest in these primitive forms has continued unabated, both as regards their peculiarities of structure and function and their consequent position in the vertebrate series, and the interrelations of the different varieties among themselves. Owing to the wide geographical distribution of the Myxinoids, the relative scarcity of individuals, and the difficulty of securing material for study, especially the living animals, previous papers have been based upon the study of museum specimens, and our knowledge has, in consequence, been very incomplete. It was my good fortune to obtain, during the summer of 1904, several hundred individuals of *Bdellostoma dombeyi* Lac. in sound, healthy condition, which I kept alive in aquaria. I was able to provide conditions closely approximating their usual habitat, and, under these favorable circumstances, I kept them under constant observation for four months. The observations made have been checked by a study of the conditions of their normal habitat. This paper, therefore, is based mainly upon a study of living individuals in conditions approaching as nearly as possible the normal environment; and these notes are published in the hope of throwing some new light upon this interesting form, and for the purpose of correcting some erroneous statements that, through lack of means of observation, have gained currency.

I wish to express my thanks to Dr. C. H. Gilbert, of Stanford University, who kindly placed at my disposal the facilities of Stanford's seaside laboratory at Pacific Grove, California; to

[1] Under the direction of Dr. Howard Ayers.

Dr. Frank McFarland for helpful suggestions; and to Mr. M. H. Spaulding for much practical help. I wish also to thank Dr. Michael Guyer, of the University of Cincinnati, for the loan of laboratory materials, and to express my obligations to my sister Louise for the very excellent and accurate drawings from which the illustrations for Fig. 1 and 2 were made.

The Myxinoid upon which the following observations were made, is the common hagfish of the Pacific coast, *Bdellostoma dombeyi* Lac. It is found in exceeding abundance in the Bay of Monterey, where it is a great pest to the fishermen. It is caught both with hook and line, and in traps. Those caught on hooks do not live long in captivity. Instead of being hooked in the jaw as is usual with other fish, Bdellostoma usually swallows the baited hook whole, and is thus hooked through the head or the body wall, hence the esophagus and stomach are more or less torn in extracting the hook. Even under most favorable conditions I have not found those caught on hooks to live more than a few hours in aquaria. The traps used by the fishermen in catching hagfish, are large wicker baskets, loosely woven, resembling lobster pots. A quantity of bait, usually pieces of squid or sardines, is put inside, and the trap sunk over night. In the morning it may contain anywhere from twenty-five to a hundred fish, mostly medium size, with a few small and several large individuals. The largest hagfish are not caught in the traps, as the meshes of the baskets used are too small for them to pass through.

The aquarium, in which I kept them, was a wooden tank, about six feet long, four feet wide, and two feet deep. It was located in the basement of the laboratory, a large, cool room, well lighted. The water in the tank was kept about a foot deep, the bottom was covered with a thin layer of clean sand, and stones were loosely piled in one corner to furnish hiding places. Four streams of fresh salt-water, coming from glass pipettes, with a length of stream varying from two to four feet between the glass and the surface of the water, played constantly into the tank, supplying fresh, well aërated water. Here the colony lived throughout the summer. Although some two hundred and fifty fish were thus kept under observation,

not more than six or eight of the total number died a natural death. Of these two hundred and fifty, about seventy-five were kept in the aquarium from six weeks to two months or more before I killed them, and more than a hundred were kept for a month before being killed.

General Description.

It is not necessary to describe the general appearance or characteristics of Bdellostoma, as that has already been admirably done (Ayers, '94) ; but one or two points of interest were ascertained in reference to their size. Of 550 specimens measured, the longest was 24.5 inches, while 104 measured 20 inches or over, and 64 were between 19 and 20 inches long. When it is remembered that of these 550 specimens, between 350 and 400 were caught in traps that did not favor the ingress of the larger hagfish, the average length will be seen to fall in the neighborhood of 19 to 20 inches. In regard to their length at hatching, the smallest free-swimming hagfish that fell into my hands measured scant two and three eighths inches (60 mm.), while a few days later I took an embryo from the shell that measured a trifle more than two inches and a half (65 mm.). This embryo was apparently ready to hatch, as it swam vigorously as soon as it was freed from the shell.

These newly hatched hagfish have the same shape as the adult, the only perceptible difference between them and their elders being that their tentacles are relatively a little longer than those of the mature fish. At the time of hatching, the head is an eighth of an inch in diameter: when from twelve to fourteen inches long the proportions of head to body are somewhat different, the head measuring from three eighths to one half inch across, and thus being relatively thinner. When about fifteen inches long, however, the hagfish begin to increase rapidly in girth, measuring at least three fourths of an inch across the head, while the larger ones measure still more. This marked change of form does not, however, as might be thought, mark the time of sexual maturity, for an individual only twelve inches long and slim in proportion was found to have a well

developed ovary, with eggs in the process of yolk development. In regard to the age at which these changes take place, we have as yet no definite information. As is already known, the process of development within the egg is slow, when compared with the rate of growth of other vertebrate embryos; and their post-embryonic growth is probably also very slow, for very small fish (*viz.*, thirteen or fourteen inches long) kept in the aquarium for three months, showed at the end of that time no perceptible change in form or size, although they fed in a normal way, or at least, as normally as any other fish in the aquarium.

One of the most interesting points about Bdellostoma, because of its supposed taxonomic value, is the variation in the number of gills. Taking the number found in the hagfish of different geographic regions as a basis, the Bdellostomids have been divided not only into different species, but also into different genera, *Bdellostoma forsteri*, of the Cape of Good Hope, with its six to seven gills on each side being placed in one genus, and the Bdellostomas of the American Pacific coast in another, subdivided into two species, *Bdellostoma dombeyi*, with ten gill slits, found in Chilean waters, and *Bdellostoma stouti*, whose usual number of gill slits is eleven or twelve, in the waters of California. Dr. Ayers ('94), after a careful comparison of the Cape of Good Hope and California varieties, concluded that there was no specific, far less generic difference between the two forms, and stated that they, together with the Chilean variety, belonged to one species, the preferable name for which was *Bdellostoma dombeyi*. This conclusion was scouted by Howes ('94), but purely on *a priori* grounds, and without any study of the forms in question. Since this time not much work has been done that would throw light on this question until within the last year or two, when Dean, studying the hagfish found off the coast of Japan, came across a variety that he called *Homea okinoseana*, distinguished by having eight gills on each side, but in all other respects like the hagfish of other localities. This Japanese variety thus fills in the gap between the Cape form with its six to seven gills, and that of Chile, with ten gills on each side.

It is worth while to study the California form carefully and in detail with regard to the gills. Dr. C. H. Gilbert of Stanford

University, quoted by Jordan and Evermann states that in fifty-four specimens which he counted, forty-one had twelve gills on each side, twelve had eleven gills, and one had thirteen gills. He states also that he occasionally found one with ten or fourteen on each side, but that the normal number was twelve. Worked out in percentages, this would read : —

Individuals with	12	gills	75.9 %.
" "	11	"	22.2 %.
" "	13	"	1.8 %.

When tested by the examination of larger numbers of individuals, however, these figures undergo considerable modification, and a new factor enters in, *i. e.*, fish that have a different number of gill slits on the two sides. The following table is given by Dr. Ayers in his paper published in 1894 :—

101	individuals had 11 gill slits on both sides ;
26	" " 11 " " " one side and 12 " " " the other ;
208	" " 12 " " " both sides ;
11	" " 12 " " " one side and 13 " " " the other ;
8	" " 13 " " " both sides.
354	total number of individuals counted.

Worked out in percentages this reads : —

Individuals with 11 slits on each side . . .	28.5 %
" " 11 " " one " and 12 " " the other . . .	7.3 %
" " 12 " " each side . . .	58.7 %
" " 12 " " one " and 13 " " the other . . .	3.1 %
" " 13 " " each side . . .	2.2 %

These figures, as will be seen, reduce the percentage of those having twelve slits on each side by one third, add very nearly one third to the percent of those with eleven slits on each side, increase slightly the percentage of those with thirteen on each side, and introduce the two intermediate forms, those with

eleven and twelve slits, and those with twelve and thirteen, these two together amounting to 10% of the total number. Dr. Ayers also says: "Of the eight 11–12 variation, where the position of the gills was noted, four had eleven gills on the right side, and twelve on the left, while the other four were just the reverse, with twelve gills on the right side and eleven on the left." On looking over the count of five hundred and fifty hagfish that I made while at Pacific Grove, I find still greater variability in the percents.

No. of Individuals	No. of Gills Left	Right	Percent
1	10	11	.18
3	11	10	.54
123	11	11	22.36
25	11	12	4.54
44	12	11	8.
325	12	12	59.09
7	12	13	1.27
15	13	12	2.72
7	13	13	1.27
550			

This larger count gives practically the same percentage of individuals with twelve gills on each side as do Dr. Ayers's figures, reduces that of those with eleven gills on each side about one fourth, increases the sum of the 11–12, and 12–13 variations from 10.4% to 16.5%, diminishes those having thirteen gills on each side from 2.2% to 1.27%, and introduces a new variation, 10–11 gills, this kind being .72% of the total number. This last variation makes direct connection with the Chilean variety with ten gills on either side. It will be noticed in my figures that in the three uneven variations, 10–11, 11–12, 12–13, the total number of individuals having the larger number of gills on the left side is sixty-two against thirty-three, almost two to one. This point will be discussed a little later.

The table following combines the records of Dr. Gilbert and Dr. Ayers with my own.

No. of Individuals	No. of Gills	Percent
4	10–11	.41
236	11	24.63
95	11–12	9.92
574	12	59.92
33	12–13	3.44
16	13	1.67
958		

A total of 958 individuals certainly gives a reasonably safe number on which to base conclusions. In this table as in the others, the fact stands out prominently that in the California hagfish twelve gills on each side is the number most commonly found. But when the number having it only amounts to 59.92% in a total of 958 eels, it cannot well be called the normal, or even the usual number, and consequently I agree with Dr. Ayers that the usual number of gill slits is eleven or twelve.

That 13.7% in a total of 958 eels is found where the number of gills is greater on one side than on the other, is to me one of the most significant features in the proper specific classification of the Bdellostomids. With six and seven gills the prevailing number in *Bdellostoma forsteri*, eight in that found in Japan, ten the number in the Chilean form, and eleven and twelve in California, varying on the one hand, though rarely, to ten, and on the other hand more frequently to thirteen, it is surely no longer possible to divide these animals into different genera and species on the basis of the number of gills alone; the count of teeth (Ayers, '94), is equally unsatisfactory as a ground for division into species, and no other ground for such division has ever been advanced.

As a matter of fact, the differing number of gills in the California hagfish is even more significant when the animal is examined more closely, externally and internally, than when the external apertures alone are counted. On dissecting the gill region of those animals with an unequal number of gills on the two sides, we find not merely that the number is variable, but also where the variation is most apt to occur. Referring back to my table, and noting the fish with an unequal number of gills

on the two sides, we find that the fish in which the greater number of gills lies on the left side (the side of the ductus œsophago-cutaneus), occur about twice as often as those in which the greater number is on the right side. But when the thoracic cavity of these particular fish was dissected, I found several cases where the number of external openings and the number of gills did not correspond.[1] Of the sixty-two individuals, in which the left gill slits outnumbered the right, six had the last gill on the left side, that which should open into the ductus, entirely wanting, making an even number of gills on each side. Two of these six were in the 11–12 group, four in the 12–13 group. In regard to the position of the external openings only one was at the normal distance from the ductus, in two the distance between ductus and external aperture was one half the normal distance between these openings, in two the external aperture lay very close to the edge of the ductus, and in one it lay in the cephalic edge of the ductus.

In other fish in which the number of gills on each side was uneven, where the greater number was on the left side, five had the last gill, that which opens into the ductus, rudimentary, varying from one fifth to one half the size of the normal gill, and in one of these the opening of the ductus was one half the usual distance from the external aperture nearest it.

In all of the fish examined by me that had the greater number of gills on the right side, the gills were normal, and normally placed. But another curious variant was found in the 12–11 series that has a marked bearing on the question, whether the change in the number of gills in the different varieties is due to addition or suppression. This individual had twelve gills on the left and eleven on the right side. The twelfth gill was of normal size and at a normal distance from its neighbor, but the second gill on the left side (counting from before backwards), was missing, the external opening leading into a short *cul de sac.* The first gill on the same side was rudimentary. If there were

[1] It should be stated here, that in counting gill slits, *i. e.*, the external apertures, the external opening of the ductus œsophago-cutaneus is always counted as one, as the external aperture of the last gill on that side usually lies not on the outer surface, but in the ductus just inside the opening.

either a fixed or a normal number of gills, this could only mean that this particular animal was a freak. But where we have variations of the species in which the number of gills ranges from thirteen to seven, and one variation (that from California), in which no number can be considered either normal or fixed, and where the last gill on one side is found to be either rudimentary or missing, there is certainly an indication of a tendency to the suppression of the gills. Moreover, in the last case the rudimentary and the missing gill are both in an unusual place (the cephalic instead of the caudal end of the line). Still another variant bears out this view. This variant was one of the even-numbered group, with twelve gills on each side. On opening the thoracic cavity, it was found that while the fish had twelve normal gills on the right side, on the left the first was missing, and the second rudimentary. As in the case last mentioned, the external aperture of the missing gill led into a *cul de sac* and there was no pharyngeal opening. In this fish there was no external mark to indicate the slightest abnormality within, which raises the question: What percentage of abnormality would be found if careful dissection were made of the gill regions of a large number of individuals?

There is no particular size in which these variations occur. In the last one given, the fish was only eleven and one half inches long; in the one preceding, twenty-one and one half inches long; the others varied between these two. It would be interesting if some young hagfish with an uneven number of gills, particularly individuals where the distance between the ductus and the nearest gill is less than normal, could be kept under observation for a number of years, to see if any changes occur during the life of the individual, or if these variations are fixed during larval growth and remain fixed during adult life. It would also be of great value in this connection if the other varieties of hagfish could be more carefully studied, to determine if the variation in the number of gills is as great as that of the California hag, and if so, when the variations occur. It should also be determined whether the number is more constant among the groups having a small number of gills.

Habits and Habitat.

The hagfish abounds in the Bay of Monterey, and is taken on the regular fishing grounds, particularly on the rock-cod beds, at a depth of about three hundred feet. The bottom here is rocky and coated with a thin, smooth sediment, but without any great amount of sand or seaweed. Infrequently it is captured in shallower waters along shore where the bottom is sandy. From observation of several hundred individuals, I find that in the aquarium they evidently prefer the hard bottom when at rest, lying for the most part coiled in and out among the rocks, sometimes with their heads under cover, but more often with about two inches of the head projecting freely into the water. When not among the rocks, or not swimming, they rest coiled up on the bottom of the tank (Fig. 2), occasionally resting on the sand, but more often on the wood where the sand has been pushed aside. At a time when there were about thirty fish in the tank, I kept watch for a week to see how many chose the different kinds of bottom. I transcribe here the notes taken at the time.

July 24, A. M. All were among the rocks but two. Of these two, one was curled entirely on the wood, the other curled on the wood with its head resting on the sand.

July 24, P. M. Two were lying entirely on the wood, the rest were among the rocks.

July 25, Noon. The same as on the previous day. After pouring water on them vigorously, and so stirring them up to swim around, six settled finally on the wood, two of them with their heads resting on the sand, while the others returned to the rocks.

July 26, Noon. Two were on the wood, the rest among the rocks.

July 26, P. M. All were among the rocks.

July 27, A. M. Two were on the wood, the rest among the rocks.

July 28, Noon. One on the wood, the rest among the rocks.

July 29. Two on wood, one on sand, the rest among the rocks.

FIG. 1.—Hagfish coiled among the rocks. × ½.

July 30, A. M. Three on wood, one of them with its head touching the sand, the rest among the rocks.

July 30, P. M. Five on wood, the rest among the rocks.

Aug. 1, A. M. All among the rocks.

Aug. 1, Noon. Five on the wood, two of them partly touching sand, the rest among the rocks.

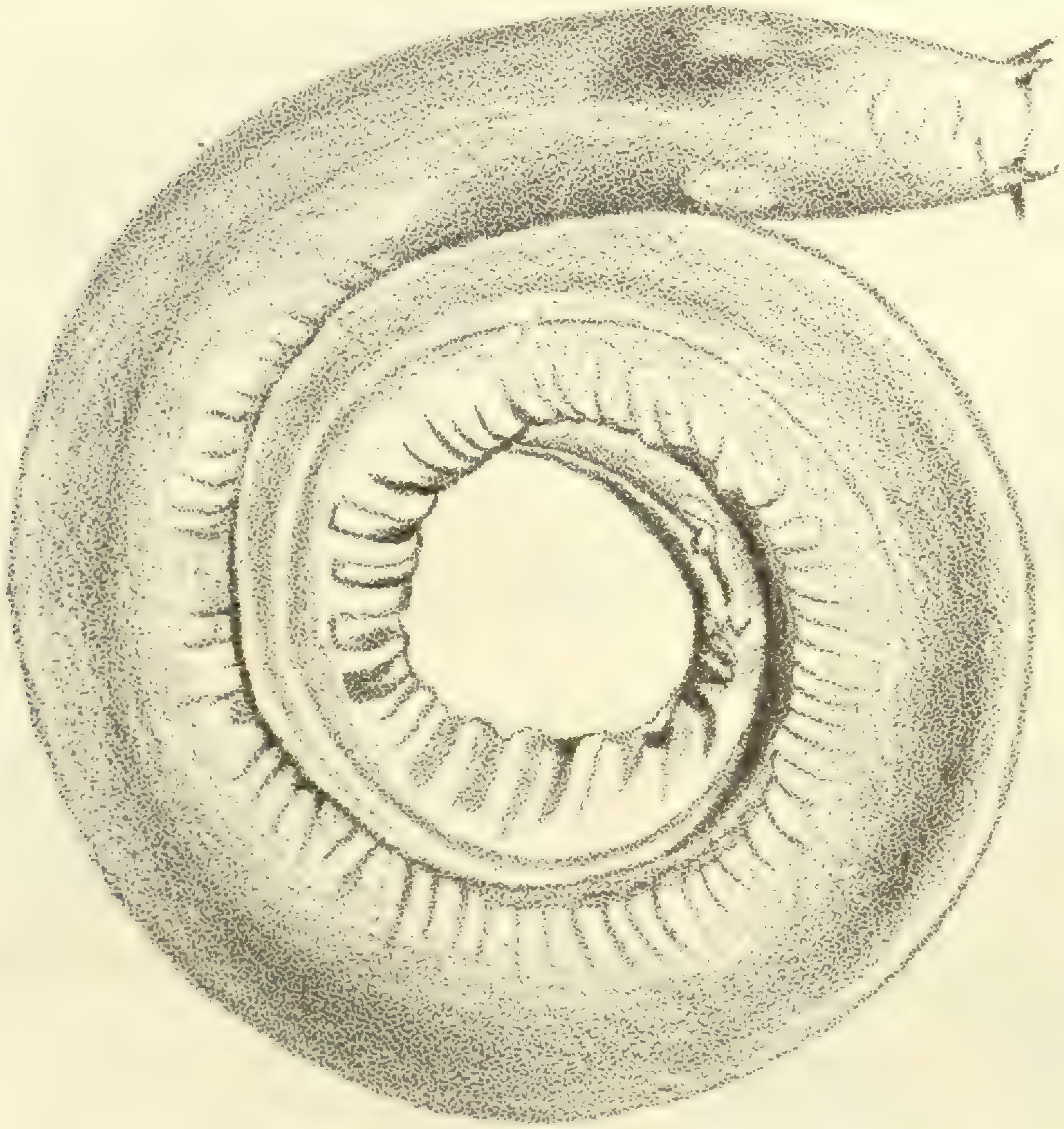


Fig. 2.— Hagfish at rest on the bottom of the aquarium. Natural size.

At a later date when there were one hundred and thirty fish in the tank, two more observations were made. The first showed only sixteen of the hundred and thirty fish on the sand, the second only fifteen. A few days later with one hundred and twenty-four fish in the tank, only twelve were on the sand.

Unquestionably then, in the ordinary circumstances of life, the hagfish prefers a hard bottom to rest on. If the rock heap

is overcrowded, and the bare wood spaces preëmpted, those left out will, for the most part, gather together and form a tangled coil, looking much like the conventional Medusa's head.

Perhaps another factor entered into this consideration of bottom, however. Was it altogether a feeling of touch that governed their choice of resting place, or did color play a part? Did they prefer the dark to the light? Two hagfish were transferred to an ordinary aquarium with glass sides and a zinc bottom. Half of this bottom was covered with sand to the same thickness as that in the large tank, and the sand and zinc were nearly the same color. The fish were kept here for several weeks, and acted just as they had in the large wooden tank. They coiled persistently on the hard zinc bottom, against the side of the aquarium, or against the iron waste pipe, seldom being found on the sand. After a few days I put a rock in the midst of the sand bottom, and after that one or the other would be found lying against it, but otherwise they shunned the sand, showing that it was purely a sense of touch that guided them.

The hagfish seem to have great power of resistance to unnatural environment, judging by the way they are handled by the Monterey fishermen, and the condition in which they reach the laboratory. They are taken from the traps between six and ten o'clock in the morning, dumped, fifty of them together, into an oblong can with a base about ten inches square and sides perhaps eighteen inches high, barely covered with water, and then stowed somewhere in the bottom of the boat while the fisherman finishes his business and rows to shore, a distance of two or three miles. Arrived on shore, they remain sometimes for several hours in the same uncovered cans before transportation to the laboratory. At the laboratory they undergo one more handling, as they are counted on being put into the aquarium. But in spite of this long wait in very little, poorly aërated water, but few die, though they are greatly crowded, and sometimes roughly handled. The long exposure to the air likewise seems not to affect them if the weather be not too warm, and the can not too full, so that the sun does not strike directly upon them. Of the first catch of about fifty, all lived; and of the second of one hundred and thirty-two, brought up in two

cans, thirty or forty were sick on arrival, but the next morning two only were dead, and all the rest in fine condition. It is noticeable that the young ones have, as a whole, more power of resistance than the old ones, for they would arrive fresh, as though just from the depths of the bay, no matter how sick many of the older ones were.

There is one unfailing test of the general condition of the hagfish: its geotropic reaction. When well and at rest, it is invariably coiled up more or less tightly, either in a spiral by itself (Fig. 2) or in and out among the rocks. Even if the fore part of its body lies free and sinuous, the tail is coiled. But if exhausted or sick, the coil straightens out, and it lies in a crescent form. The sicker it is, the straighter it becomes, and when dead it lies entirely straight.

The hagfish can live out of water without injury for a great many hours if kept in a cool, damp place. I often found on visiting the tank in the morning, that one or more of the smaller fish had found the water outlet while swimming in the night, and had slipped to the floor. They would be tightly coiled on the cool, moist cement floor, and were as agile and active there as in their native element.

There is one condition, however, that the fish cannot endure: a rise in temperature. The water on the surface of the Bay of Monterey averages in summer 64° F. or 17.7° C. What it is at a depth of two hundred feet, I do not know, nor how cold it gets in winter. But the air at Monterey is never so cold as to kill palms or heliotrope, so the water cannot become very cold. The water in the tank in which I kept the fish averaged 22° C., and in that they throve. On a warm sunny morning, I placed two young hagfish in a tank about three feet long by one foot wide, covered them with about five inches of fresh salt water at 22° C., and placed the tank by a window, where the sun shone directly into half of it, leaving the other half of it shaded. Under the heat of the sun the water in the tank rose gradually to 30° C. As the water became warmer, the fish grew very restless and languid, swimming constantly, not rapidly as usual, but with a slow, jerky movement as though seeking to escape the warm water. At the end of two hours and a half one of

them was lying almost straight. Both were put into the small aquarium with running water at a temperature of 22° C.; they swam freely for a few minutes, then settled down against the outflow pipe, having regained their normal habit. This was between half-past twelve and one o'clock. It was an exceedingly warm day, the thermometer standing at 89° F. in the shade, and the aquarium was so placed that the afternoon sun streamed directly upon it. About five o'clock I noticed that the two hagfish were very languid and stretched almost straight. On testing the water I found that it had risen to 29° C. Suddenly, the hagfish, without anything being done to disturb them, began to swim in a very violent, jerky way, and to throw out strings of slime, which is never done except when they are irritated. They would swim and stop intermittently, always lying at full length when at rest, and swimming so irregularly and violently as to injure themselves. When put into cooler water, 22° C., they immediately settled down quietly, half stretched out. I placed them in a small wooden tank in the cellar, by the large tank, in order to keep them separate from the other fish for a while, and note what after-effects there might be. The next morning one of them had escaped to the floor, together with two from the large tank. Of these three, two were entirely normal, and one was dead, in all probability the one that had been exposed to the heat the day before. The other hagfish grew steadily more languid, and died at noon the next day, two days after the experiment. Both fish were in a normal condition when the experiment began. It was positively the heat from which they suffered, and not the actinic rays, because they had been exposed to brilliant sunshine every afternoon for a month, and no ill effects had followed. The day they were affected was the first day there had been a marked rise in temperature.

Taken as a whole the hagfish do not lead an active life. When thoroughly aroused and on the alert, they swim at a very high speed, with a graceful, serpentine motion, but for the most part, they lie placid, perhaps motionless, perhaps lazily moving their heads from side to side. They are more active by night than by day. In the daytime more than once I found some of

them asleep. There was no outward difference between the sleeping ones and the others; all were curled quietly on the bottom, but if by chance a sleeping one was touched, instead of wriggling away it remained passive, unless perchance it coiled tighter, retaining its coil even when lifted from the water. Once I found two sound asleep, surrounded by a mass of slime in which they had in some way become lodged. The slime served them as a buoy, and they were floating quietly in it on the surface of the tank, circling around with the current. I took them out and stripped their covering from them, but they hardly aroused while I did so, and settled down to sleep again as soon as they were put back into the tank. Sometimes after a minute or two of handling they awake, but an interval elapses between their first stirring when they squirm uneasily in the hand, and full alertness when they swim rapidly away, or if held tight, they make the usual vigorous efforts to free themselves. If before the fish is wide awake, it is put back gently, it can drop off to sleep again. I once lifted a sleeping fish, dropped it into a pail, carried it a distance of more than two hundred feet, took it out of the pail, and started to decapitate it. All this motion followed by the tight grasp of my hand and the first touch of the shears, usually the first signal for the most frantic struggles, did not rouse it perceptibly, and its head was off before it began to squirm.

It is interesting to watch their movements, while they are becoming accustomed to confinement. When the first lot of fifty were placed in the tank it contained only water. They were normal fish in every respect and when first placed in their new home they swam around very vigorously, threw out a great deal of slime when touched, and were on the whole, unusually excited. After a short while, they settled down on the bottom, in the usual coils (Fig. 2), an occasional group of three or four together, the rest separate. Two days later sand was put on the bottom, and the rock pile built at one side. In a few hours all had burrowed among the rocks. There they lived very quietly, seldom moving when left to themselves, except at night. For the first four or five days they were easily aroused by dipping a small pailful of water from the tank and pouring it on

them. When this was done they would throw out great quantities of slime, and wriggle among the rocks, some of them leaving the nest, and swimming rapidly around the tank. When the sixth day came it was harder to rouse them, and for about ten days following they could hardly be stirred, neither throwing out slime nor swimming when the water was troubled. If one was lifted on a stick and moved, it quickly settled down wherever it might be, finding its way back to the rocks later. This was not due to illness, for their positions were normal. Toward the latter part of the third week, they became more active, lying quietly in the rocks when undisturbed, but rousing easily and getting much excited when water was poured on them from a pail, swimming freely and throwing off slime again, as they had done at first.

The second lot I received went through the same stages of liveliness and torpor as the first, and in about the same time intervals.

The so called slime they throw off is their chief means of protection. It often enables them to escape from whatever would catch them, by forming a covering so slippery that it is difficult if not impossible to get or keep hold of them. The thread cells are not emitted except upon sufficient provocation. I have often lifted them carefully and had them slip through my fingers without causing thread cells to escape. It is their response to conditions that irritate; they are always thickly surrounded with slime when caught on the hook, and the occasional ones that died natural deaths in the tank had always thrown off a considerable amount of slime in dying.

The question of what and how the hagfish eat, is one that has been much discussed in previous papers about them, some writers maintaining that they are parasites, and all stating that they are extremely voracious. In regard to this latter point the evidence comes from the fishing grounds. When the night lines are examined, one third or more of the hooks hold hagfish and the fish on many of the others have been entirely eaten away, nothing but the skin and bones being left. The hagfish has bored inside the skin and eaten all the soft parts, and is sometimes caught in the very act of wriggling away at the close of

its meal when the fish is taken from the water. From what I saw of their behavior in the tank, though, I conclude that this behavior shows the inordinate numbers of the fish in the bay, rather than extreme voracity. Those that I had were small feeders, and went a long time without eating. As a matter of fact, they ate so infrequently that I was not able to experiment with them and test their likes and dislikes as much as I wished.

According to the fishermen, the best bait is squid; failing that, they use herring, or as they call them, "sardines."

My first lot was caught on a Friday. The following Monday I put into the tank eight dead flounders about ten inches long and three inches wide. About a dozen of the fifty hags ate freely, some of them ravenously. But although several of the flounders had been partly eaten, the total consumed did not amount to more than two flounders.

It is very interesting to see them eat. The process may be easily watched when they are fed with small fish, or are just beginning on a large one. The feeding apparatus, described by Ayers and Jackson (:00), consists of a heart-shaped plate composed of symmetrical halves that open out and fold together like the leaves of a book. This plate bears on the dorsal surface of each half a double row of horn teeth, their points directed meso-caudad, and it lies imbedded in the membrane of the ventral wall of the pharynx.

When the animal feeds, the tooth plate, which is really a modified and movable lower jaw, and in no sense a tongue, as stated by Müller ('34) and P. Fürbringer, is thrust out of the mouth, and its fore end is drawn down so that it takes a position almost perpendicular to the long axis of the body. The two halves are at the same time drawn apart, so as to present an almost flat surface. Placing this flat surface against the fish to be eaten, the hag draws the halves of the tooth plate together, thus tearing off a portion of the food, and then withdraws it into its mouth. It swallows the food very rapidly, and immediately sticks out the tooth plate for more. There is no sucking motion as Fürbringer has said; the hagfish simply rests with its nose against the fish, and if, because of a current in the water, or through the vigor of the attack, the food is moved from its

position, the hagfish swims rapidly after, keeping in this way in constant touch with it.

This tooth plate is worked by five muscles, three of which form a unique mechanism called by Dr. Ayers the "club." These muscles lie close to the ventral surface and may all be seen when the ventral skin and body musculature are deflected back. The two that do not belong to the "club," lie ventrocephalad of it (Fig. 3). The more lateral one arises as a narrow

Fig. 3.

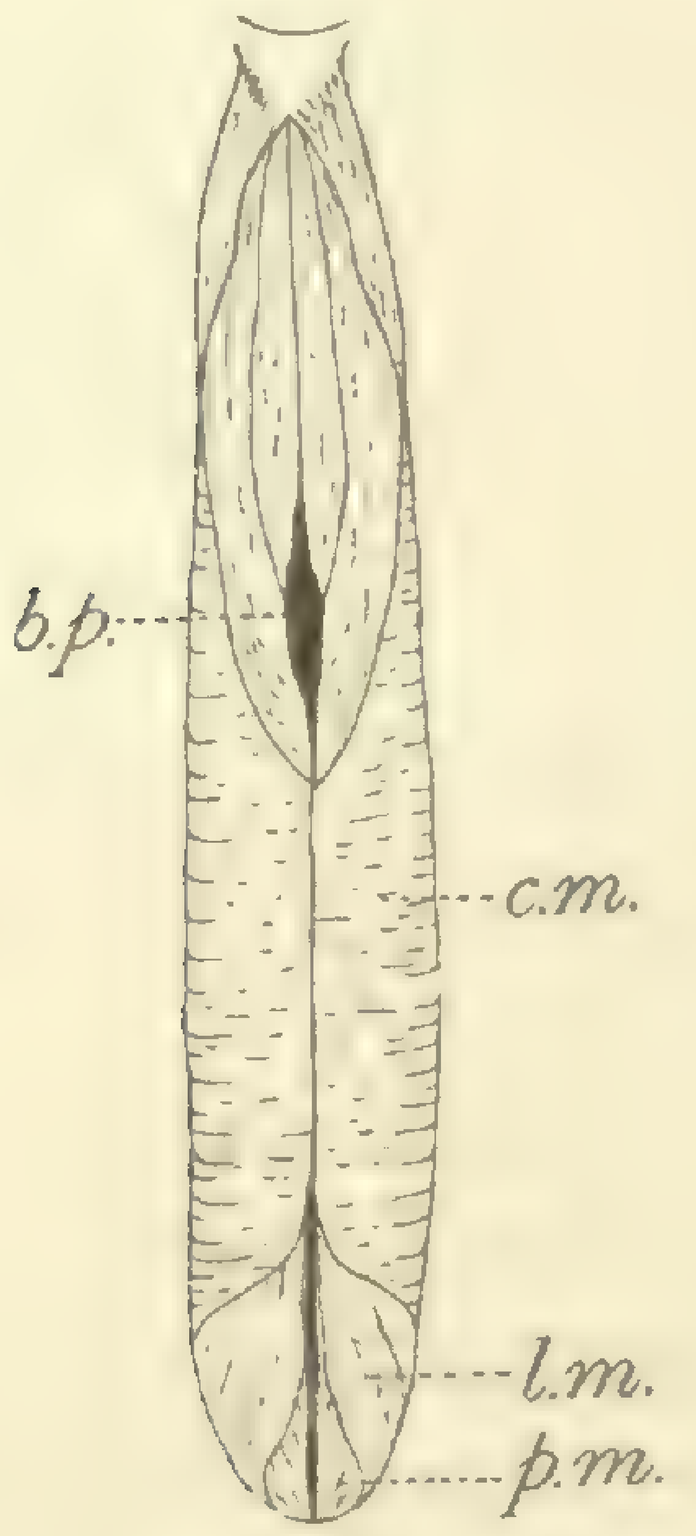


Fig. 4.

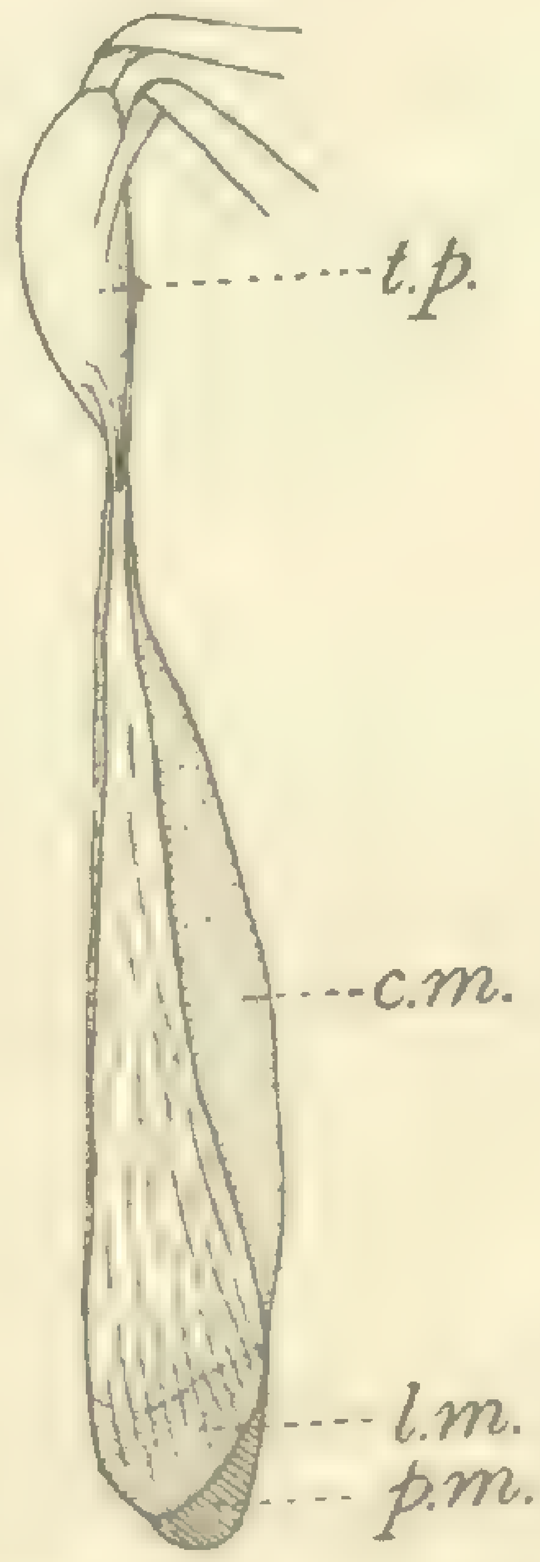


Fig. 3.—The "club muscle" and its accessories. Ventral view. *b. p.*, basal plate; *c. m.*, circular muscle; *l. m.*, long muscle; *p. m.*, perpendicular muscle. ½ natural size.

Fig. 4.—The "club muscle" and its accessories. Lateral view. Half of the circular muscle has been cut away in order to show the long muscle. *c. m.*, circular muscle; *l. m.*, long muscle; *p. m.*, perpendicular muscle; *t. p.*, tooth plate. ½ natural size.

band of fibers along the lateral edge of the cephalic half of the caudal section of the basal plate, runs cephalad, then curves slightly mesad, joining its fellow of the opposite side in a common aponeurosis, about a quarter of an inch behind the mouth opening. The aponeurosis continues forward until it reaches the mouth opening, where it fuses with the connective tissue which supports the mucous membrane of the lower lip; here it divides, each half deflecting posteriorly and laterally, to attach itself near the cephalic border of the tooth plate. The contraction of this muscle helps the two halves of the tooth plate to close together.

This mandibular muscle (Figs. 3, 4), is called by Fürbringer, m. copulo-glossus superficialis, and by Müller, "der oberflächlicher Vorzieher der Zunge." Both of these names are now inadmissible, as we are dealing with the lower jaw and not with the tongue as these authors thought.

Mesad of this superficially placed mandibular muscle lies Fürbringer's m. copulo-glossus profundis, Müller's "tiefer Vorzieher der Zunge." This muscle (Figs. 3, 4), consists of a lateral and a mesial division which join together at the cephalic end. The lateral division arises from the lateral edge of the caudal end of the third section of the basal plate. Its fibers run laterally, then curving, run cephalad along the border of the mandibular muscle last mentioned. The mesial division also arises from the lateral edge of the third section of the basal plate, between the points of origin of the lateral division of this muscle and the superficial mandibular muscle. It runs forward between the lateral division and its fellow of the opposite side, being separated from the latter merely at its hind end. The combined mesial and lateral divisions of each side fuse together at the cephalic end into a common tendon for the two muscles. This tendon runs cephalad between the basal plate and the aponeurosis of the superficial muscle, turns dorsad at the cephalic end of the latter, and runs caudad to the tooth plate where it divides again and is inserted midway in the length of the latter, close to the median line. This muscle, by contraction, draws the tooth plate forward, and by contracting to its full extent pulls it out of the mouth and into the vertical position.

The other three muscles that manipulate the tooth plate form a structure aptly named by Dr. Ayers the "club muscle." This "club" is between three and four inches long and consists of a hollow circular muscle, a long muscle, and a perpendicular muscle.

Of these three, the long muscle (Fürbringer's m. longitudinalis linguæ, Müller's "innere Längsmuskel der Zunge") is the only one in direct connection with the tooth plate. This long muscle (Figs. 3, 4, *l. m.*), is about three inches long, and from half to three quarters of an inch across its caudal end, tapering at its cephalic end to two tendons, one of which lies enclosed within

the other. These two tendons run cephalad to the tooth plate, just before reaching which they separate, the outer tendon attaching itself to the ventral surface of the tooth plate along the median line, the inner one dividing into two which curve laterad, run ventrad of the plate, and insert near the lateral border. The fibers of the long muscle are directed longitudinally. Shortly before reaching the caudal end, they separate into two divisions, permitting the passage between them of the perpendicular muscle. They curve around this, curve mesad toward each other, and end in a thin fascia that forms a partition between them. When this long muscle contracts, it draws the tooth plate back into the mouth, and then flattens it out again.

But as the long muscle is fixed only at one end, it cannot contract without assistance, hence the perpendicular and circular muscles.

The perpendicular muscle (Müller's "innere senkrechte Muskel der Zunge"), is a short rather stout muscle, arising from a small cartilage on the ventral surface of the "club," and running cephalo-dorsad, where it ends in a bounding fascia (Figs. 3, 4, *p. m.*). This little muscle, surrounded as it is by the long muscle, acts as a fixed point for the latter to contract around, and by contracting itself, increases its diameter as a pillar, and by thus taking up more room, helps the other to contract.

The circular muscle, also one of the mandibular muscles (Fürbringer's m. copulo-copularis, Müller's "höhler Aussermuskel der Zunge"), is a hollow cylinder surrounding the long muscle (Figs. 3, 4, *c. m.*). It begins about a quarter of an inch caudad of the tooth plate, and continues to within half an inch of the caudal end of the "club." It is much thicker at its cephalic end, where the long muscle consists of little more than a tendon, than at the caudal end, its walls growing thin there, and the long muscle increasing in girth. It is covered with an aponeurosis into which its fibers are set. Its fibers run circularly at right angles to the long axis of the "club." In cross section the walls of the circular muscle are seen to be crescent-shaped, thick on the ventral surface and at the sides, but thinning as they proceed dorsad, until only a thin layer or fascia is left to

close the cylinder upon its dorsal surface (Fig. 4). The circular muscle by contracting around the long, forces it back to where it has more room in the hind end of the "club," and so helps it to withdraw the tooth plate. Considering the extreme cumbersomeness of this device for using the lower jaw, it is rather remarkable that the hagfish can move it with the lightning-like rapidity with which it does.

If the fish is large enough to permit of it, the hagfish makes only one opening in the skin, and pushing in through that, works its way around inside, eating as it goes. I have seen three hagfish attack one fish through the same opening, their heads entirely hidden in the fish's body, their tails flapping like streamers in a wind as they pushed the fish in front of them, each striving to outdo its neighbor. They usually eat together, and I have often seen several of them at work on one dead fish, while other fish would be lying untouched in the aquarium. Under these circumstances it is no longer permissible to hold that the large fish found to be reduced to skin and bones, have been thus denuded by a single hag, though it may well be that only one of the number is detected in the act of leaving it.

The hagfish do not eat often. After the first feeding in captivity, a week passed before they were given anything more. Then flounders were given again, but only half a dozen ate. A week later, when flounders were offered them for the third time, only three touched them. At the end of another week they were given a rock cod, but did not touch it. Four days after, they were given a small cod and two small flounders, but did not touch them. It was not that the food did not suit them, for they eat any fish on the lines; they were evidently not hungry. Still I thought I would see if a different kind of food would tempt them more, so the next week, thirty-five days after they were caught, and seventeen days since any of them had touched food, and about a month after most of them had fed, I gave them five sardines, very flat fish, about eight inches long and two inches broad. There were about thirty hags in the tank, and by this time most all of them seemed to be hungry, for they ate all but one of the sardines. This was the only time ravenous hunger was observed during the summer. The

moment the first sardine was thrown into the water, the hagfish near it woke up, and went to it; other fish were thrown in, and in a minute or so the whole tank was alive. They ate ravenously, five or six crowding each other around one sardine. Within a few moments, twenty-one and a half of the two dozen sardines had been disposed of; the rest they finished during the night. As they seemed to be hungry, six sardines were given them four days later. The first was placed in the water very quietly and with as little jarring as possible; I had already noticed that an object could be placed quietly in the water without their paying any attention to it. When this first sardine was put in, however, several fish within six or eight inches of it were instantly on the alert, showing that they smelt it. They swam over to it, nosed around it, and ate a little. In a minute or so several fish at a greater distance stirred and came over, and they too nosed around the sardine. Other sardines were then thrown in, but comparatively few of the fish ate, and these only lightly. Although there were more than one hundred hagfish in the tank, only two and a half sardines were disposed of.

They were not fed again for two weeks and a half. Then seven sardines were given them. They woke up instantly and examined them, nosing around them as a dog does around a bone. About a dozen gnawed the fish in various places, and by the next morning three of the sardines were entirely eaten, but the others were untouched.

Of course in making these observations it was impossible to tell which fish fed at the different times, and how long any one fish went without food. But the day after the two dozen sardines were eaten, two fish were taken upstairs and placed in the small aquarium there, where they were kept for a month. During this month a sardine was offered them twice, and left with them for thirty-six hours, but was untouched on both occasions. It is thus apparent that they can go a long time without food, and do not eat nearly so heartily when they do feed as has been supposed. The explanation of the greater hunger of those freshly caught probably lies in the fact that they were rather hungry when they found the food in the trap, and that some of them had not been able to get enough of it to satisfy them.

The question of parasitism can, I think, be answered fully in the negative. There is nothing in their structure to indicate degeneracy, either of the feeding organs, or of the senses with which they search for food. Moreover, they have no means of attaching themselves to living prey, unless that prey is held helpless on a line or in a net. They have neither hooks nor a sucking disc with which to hang on, and the palatine tooth is too short and placed too far back in the mouth to be used for this purpose. They can only swim and bite, and I hardly think they could make much headway with a powerful free-swimming cod or halibut.

There is one food, however, of which the males are extremely fond, and that is the eggs of their own kind. They eat these in great abundance, swallowing them whole. One evening, just before leaving the laboratory, I found a dead fish in the tank. It was a female with eggs almost ready for oviposition, and on lifting it the eggs were pressed out. I left them in the tank, twenty of them all told, to see what would happen. The fish had been fed the day before, and had eaten scantily, so they were not hungry, but by morning all but one of the eggs had been eaten ; a day or so later I found the empty shells cast out. The egg is swallowed whole, and its contents slowly digested out of it by osmosis, leaving the shell untouched, or at most with only a prick in it given in passing over the teeth. I have examined several hundred eggs that had been pressed out from the intestine, and were in all stages of digestion, from the first murky clouding to the breaking and drawing off of the contents. In none of them was the shell really broken. In many of the largely digested ones there was no sign even of the pinhole prick, while in others quite undigested, the perforation of the shell was very evident. It must therefore be purely accidental and in no way necessary to digestion.

SENSE PERCEPTION.

The hagfish has all of the usual sensory nerves and sensory organs, barring the lateral line organs, possessed by the higher fishes, but they are all in a very primitive condition. It was

interesting by experiment to see what use was made of them. The eyes are not exposed on the surface, like those of other fishes, but are covered by the skin, which is, however, translucent for an area of about a square centimeter over them. There is nothing, therefore, to prevent the free passage of light. It has already been stated that when in the tank they would lie sometimes with their heads hidden in the rocks, but just as often with them projecting out into the light. It was suggested to me that this might be due to their wanting open water to breathe, and that possibly, other things being equal, they would prefer the dark. So to test it, two fish were placed in a large pan, three feet long by a foot wide, and half of the pan was covered making it very dark, while the other half was left open. It was a gray day, which made the light in the open end of the pan what they were accustomed to down in the tank. Both the fish were sluggish and did not swim much, but they were disturbed a number of times, and made to change positions. Each time when they settled down they seemed regardless of the light. They would settle quite as often at the light end of the pan as at the dark end. To make a surer test, two lively young fish were placed in a round dish about a foot in diameter and covered with an inch of water. After swimming rapidly for a few minutes, they settled down into tight coils. The dish was placed on the table in the photographic dark room, and a microscope lamp was lighted. The lamp had a light-tight iron chimney, with a curved glass rod coming out opposite the flame to concentrate the light on the disc at its far end. This disc was about a centimeter in diameter. The fish chosen were particularly valuable for the experiment because they were young and the skin over the eyes was unusually clear. In one of them it was transparent, so that I could distinctly see the eye beneath it. In the dark room the circle of light coming from the glass disc was held an inch above the water. It could as well have been at the other end of the room as far as observable results were concerned, for they paid no attention to it. It was moved closer and closer to them, finally being placed under the surface of the water, and within an eighth of an inch of their skin, without obtaining an observable reaction. At all of these differ-

ent distances, the light was moved so as to fall on different parts of each fish's body, eyes, tentacles, head, back, sides, etc., and there was no reaction to it by either hagfish.

In regard to whether they could perceive objects or not, the first thing that I noticed about them was, that when swimming rapidly in crossing the tank from side to side, they would repeatedly strike the tank head foremost; and when one was taken from among the rocks and held for some minutes in the hand or dropped in a corner of the tank, it would proceed very cautiously, moving its head from side to side, keeping its tentacles outstretched, and apparently depending on them for knowledge of its surroundings.

The two young hagfish referred to above I also tested for image perception, holding various objects close over their eyes, and bringing them nearer and nearer. They showed no reaction, no matter how near the object was, until the surface of the body was touched, when they jerked their heads away. These hagfish were neither sleepy nor sluggish, but were undoubtedly normal. The conclusion drawn is, that the perception of variations of light and shade even when extreme, does not irritate the eyes.

The evidence in regard to their hearing is just as negative as that concerning their sight. I was not able to find any noise or sound to which they would respond.

In testing the sense of touch, very different results were obtained. If the tank is jarred, the fish immediately tighten their coils; if they are touched suddenly they jerk their heads away. When they are swimming, and often when they are at rest, the tentacle crown is extended, and the tentacles, moving back and forth, sense the water currents or anything they may strike against. When swimming in search of anything, the tentacles are always on the alert, as tactile outposts or sentinels.

The same two fish that were studied for light perception, were also experimented on for touch, and were touched lightly in different places with a straw, a glass rod, and a fine needle. When touched lightly, fish A would not respond, but fish B would jerk itself away. Touching any part of the skin, whether of the head, over the eye, on the back, on the side of the body,

etc., gave the same reaction for each fish ; A, as a rule, reacting less energetically than B. But if the tentacle of either fish was touched, the reaction was much greater, each fish jerking the tentacle sharply aside. There seemed to be no difference in sensitiveness between the base and the tip of the tentacles, and the fish responded the most of all upon being touched in the angle formed by the tentacle with the head. B jerked away when touched directly over the nose, but A did not notice it, and neither gave more attention to being touched over the eyeball than in any other part of the skin.

In most cases when they react to the touch stimulus, they respond by curling the body tighter.

I placed a third young hagfish in the dish with the two, and then tried placing various liquids on or near them by means of a pipette. First as a control, I used ordinary sea water. When a stream of this was directed from a pipette against the tentacles and rim of the nose, they would draw the head a little to one side.

Ordinary alcohol was dropped in the water, one drop after another in front of B, within a half inch of the tip of its nose. Some of the drops touched it in mixing with the water, others did not. The contact of alcohol did not produce observable reaction until after twelve drops had fallen, when it moved away. When fish C was treated the same way, eighteen drops fell before it moved ; the nineteenth touched it and it moved its head aside. B was touched again just as before, and again jerked its head away after the twelfth drop. The thirteenth drop placed in front of it at the usual distance, made it swim off to a different part of the dish. In this new position, eleven drops were given it one by one and it moved at the eleventh. C, treated a second time, took twenty drops before giving any reaction. The twenty-second made it a little uneasy ; at twenty-three it moved its head slightly, and at twenty-four swam away. I followed it with another drop, and it went back to its old place. Three minutes later, it took five drops that all touched it in mixing. It quivered slightly at the third and fourth, but did not move aside until the fifth.

One drop of hydrochloric acid placed in the water near the fish

will make them jerk violently away if it touches them in any place while mixing with the water. A drop of strong ammonia does the same. The ammonia throws down a precipitate of ammonium chloride on the surface of the water, and if this drifts against them before dissolving they show extreme irritability. In all these cases it is largely the sense of touch that is affected, as the reaction was the same whether the mixing drop touched the tip of the tentacle, the rim of the nose, or the side of the head, and it was the touching of the mixture that produced the effect, except in the case of the alcohol, for it was found that when the visible mixture of the drop of acid or ammonia stopped even an eighth of an inch away from the fish, there was no reaction. With the ammonia this could be seen still more plainly, for wherever the ammonia was dropped, it was not until the ammonium chloride touched the skin, whether on tentacle, tip of nose tube, or skin at the side of the head, that the jerking away occurred. With the alcohol it was sometimes a drop that touched that caused the effect, sometimes not. With the many drops put in, only some of which touched the hag, and those not affecting it, it may be that the sense of smell was excited, or it may be that the alcohol finally irritated the mucous membrane lining the nasal tube, or possibly the skin of the tentacles. The foregoing experiments with the acid and ammonia were begun at half-past three o'clock, and were continued until five. By that time the eels had become very languid and were lying in the crescent shape. The next morning they were all right again.

Notwithstanding the negative results of these experiments in regard to the sense of smell, there is no question but that it is a most serviceable sense for the hagfish. As they cannot see, it is the means by which they know when they are near food. I cannot tell at what distance they can detect an object by the sense of smell. When the dead fish was placed in the tank, as stated above, and the hagfish within six inches were aware of it immediately, it took a perceptible time for those farther off to become so, but the scent reached those as far off as eighteen inches to two feet. How much farther it would go I do not know. It probably varies with different individuals.

I was not able to gather any data as to the sense of taste. So far as may be judged from observable reactions, the senses of touch and smell are the most important in the life of the hagfish. Watching its life for four months and examining its brain, both confirm this. Several times, to see what would happen, I took apart the rockery, transferring it to the other side of the tank. The hagfish, suddenly deprived of their place, were restless. First they moved their heads and the fore part of their bodies, groping around, and then began to swim. They swam in a slow, searching manner, sometimes feeling their way along the side of the tank, and always with their heads moving slowly from side to side, tentacles on the alert. Most of them, when they touched the rocks with a tentacle tip, would recognize them instantly, and go right in. Many on approaching within an inch or an inch and a half of them, would plunge straight for them, probably having smelt them. But there were others that, while searching, would glide directly over the rocks, perhaps even touching them with their bodies or the sides of their heads, or even with their tentacles, yet would give no evidence that they noted their presence ; instead, they would continue their search farther afield, and eventually get back to them again.

On the other hand, they sometimes have a wonderful surety of motion. One morning I found one hagfish that had made a loop of its body, and was lying motionless, while three others were swimming through the loop, one after the other. They would dash through, describe a large circle from eighteen inches to two feet in diameter, come back to the starting point, and plunge through again. The hole in the loop was less than two inches across, and in the few minutes that I watched them, not one of the three hesitated, or failed to pass quickly and surely through the loop.

But they do not always carry sense of direction so well. If I took one away from the rocks, and dropped it immediately six or eight inches off, it generally went straight back. But if I held it a minute or so, or dropped it farther away, it would have to search for its resting place. Sometimes it would search and find it ; sometimes, not finding it immediately, it would swim slowly around and settle down.

In other ways there is a difference in sensitiveness in the hagfish, showing in the varying strength of the reaction caused by different stimuli. The difference in the two fish with regard to the alcohol was one of these. At one time when two healthy fish were in the small aquarium, I struck the table on which the latter stood with a heavy iron bar, thus giving the aquarium a decided jar. The fish responded by tightening up their coils at the tail end, and then loosening them again, one fish reacting more strongly than the other. I pounded regularly at intervals of about five seconds, and they responded each time, the one always in a slightly more marked degree than the other, but the responses getting less and less, until at the twelfth blow they were no longer given. Half an hour later, when they were lying quietly, I tried again. This time they stopped at the eighth pound. The next day they were apparently more irritable, for they were still responding at the twentieth blow.

Their movements of defence are interesting. When caught, their efforts of escape are purely of the reflex order, trying to slip out of what is holding them. They wriggle and squirm to get away, throwing out their heads and wrapping their tails about one's wrist, but they rarely bite. The tooth plate is a formidable weapon, but they seldom use it as such. Of all the five hundred and fifty hagfish handled last summer, but few snapped, and only one bit. This is in keeping with the experience of others who have handled them.

Their power of reflex action is very strong, and when the head is cut off the body wriggles as violently without the head as it could with it. It will wriggle of itself for several minutes after the head is off, and after it becomes quiet it will respond, if touched, for several hours after the beheading, two or three hours in any case, and with the younger, smaller fish much longer. A fish was stretched out and nailed to a board, and injected through the heart with methylene blue. Forty-five minutes later the head was cut off, and the body thrown into a pan. Two hours after this a second headless body was thrown upon it and the first squirmed and tied itself into a knot.

These reflexes are just as strong in the tail end of the body as in the head end. Once in trying to open a hagfish to remove the

ovary, the fish, although it had already been beheaded, squirmed so that it was almost impossible to operate. The body was cut in half in the hope of quieting it, by cutting through the spinal cord, but both halves squirmed as vigorously as ever.

The most remarkable case of all was that of a young hagfish eleven and a half inches long. It was beheaded before noon. At five in the afternoon its body was opened its entire length. As soon as the instrument touched it, it squirmed vigorously, tying itself into a knot. In ten minutes the examination was over, it was thrown into the ocean, and my attendant at once reported that on touching the water it swam away. It would be interesting to know how long its swimming continued.

In contrast with the spinal cord, the life of the brain cells is short, particularly those in the fore part of the brain. When the fish were beheaded, the brains had to be removed and put into the killing fluid within an hour or they were valueless for histological work.

Reproduction.

The hagfish have only one reproductive organ, a peritoneal fold hanging from the roof of the right half of the body cavity. When the eggs or sperm are ripe, the organ fills the entire right side of the body cavity, but after discharge, it is all absorbed except for a small matrix at the caudal end. In this stage the sex of the organ is distinguishable only by histological examination. It appears as a small thickly gathered frill, the outer edge of which holds a multitude of tiny spheres, the undeveloped ova or sperm spheres respectively. As the hagfish has no external marks of sex, in this stage it requires a microscope to distinguish between male and female animals. As the process of ripening proceeds, the frill becomes thicker, and extends cephalad, the spheres becoming more numerous and the ova growing ovoid in shape. The frill may extend possibly one third of the way cephalad, before its edge becomes thicker, or the sex apparent. I cannot state positively at what length this occurs, but by the time it has grown halfway along the cavity, the edge is at least double in thickness what it was

in the beginning, and the sex plainly marked, the eggs being ovoid bodies, about two millimeters long and the sperm spheres larger than before.

Only between twenty and thirty egg cells develop into mature ova during one cycle, many of those starting development being arrested when from two to six or eight millimeters long, and the other spheres failing to develop. Whether this applies to the sperm spheres could not then be ascertained. No new facts were observed relative to the question of hermaphroditism. This condition was not present in any of the relatively few fish examined by me.

The hagfish oviposits at all seasons of the year, but probably a great many more mature in the spring than at any other season; and I think that no individual deposits eggs more than once a year, perhaps not so often as that. Of those studied by me between July 1 and October 30, about half were in the resting stage where it was impossible to detect sex difference. Among the others I did not find any fully ripe male; of the females only two had reached maturity, and of these but one produced ripe eggs, while the other died from some unknown cause before the eggs were deposited. The eggs are easily felt through the thin body wall in handling the fish, and I had from ten to a dozen fish with very large eggs under observation for six weeks or more, but the time was not sufficient to bring more than the one fish to the point of ovipositing.

The supposition that the greater number of hagfish breed in the spring is also supported by the relative numbers of eggs found at different times of the year. Embryos can be found at any time in various stages of development, but most of those taken even in September are small.

Of thirty-seven embryos gathered between September 8 and September 15, eleven were too small to be taken from the shell, eleven more were less than 30 mm. long, six were between 30 and 40 mm., seven between 40 and 50 mm., one 54 mm., and one 65 mm. This last was evidently within a short time of hatching, as it swam freely when taken from the shell. During this same week only four recently hatched hagfish were brought in, and of these one was 60 mm., one was 80 mm., and one 83

mm. The fourth had lost the fore part of its head so that I could not tell its exact length. I was told by the fisherman that eggs in which blood vessels could be seen were not very numerous before September. Late in September I received several very mature embryos and newly hatched young, and also some eggs in which the embryo was not more than eight millimeters, and was told by the fisherman that if I wished some young about four or five inches long to send for them at Christmas time as they were most easily obtained then.

The eggs are difficult to find. They are almost never taken in deep-water dredging, even in beds where the fish are very numerous. The United States Fish Commission steamer *Albatross* was out for three months in the spring of 1904, exploring the bottom of the Bay of Monterey, and in all that time only one egg was brought up by the dredge. On the other hand, Mr. Frederick Woodworth told me that in dredging for molluscs on a mud bottom at a depth of from twenty to twenty-five fathoms, he had several times brought up hagfish eggs. He says also in answer to a letter of inquiry on the subject: "I find from the fishermen that they have taken strings of eggs in from fifteen to eighteen fathoms with their mesh nets in muddy bottoms; with trawls they have taken them in as deep water as thirty-five fathoms, always on muddy bottoms." The one set of eggs that was laid in my aquarium was laid on the sand bottom, though there were the rock heap and the bare wood for the fish to choose between. Under these circumstances it is certainly probable that the hagfish do not breed in their usual habitat, but seek shallower water and a soft bottom to do so. The explanation for this will be found in the food habits of the young.

In gathering the eggs, aside from dredging, advantage is taken of the fact that they are eaten by the males. The fishermen set traps or lines for the fish, and when they are caught, hold them firmly by the head with one hand and "strip" the body with the other, thus forcing out any eggs or newly hatched young, for these are also eaten. Under these circumstances, only a very small proportion of the eggs obtained are good for histological study, as most of them have been more or less digested. Even if they are sufficiently uninjured to use for his-

tological purposes, the embryo is generally so much hurt that it will not develop further but must be fixed at once.

Hagfish embryos are exceedingly slow in developing. The evidence pieced together from the eggs brought in and the statements made by the fishermen as to the seasons when certain sizes of embryos were most easily found, was confirmed by the development of the seven eggs laid in the aquarium.

The average egg when laid is about twenty-three millimeters long (though some are shorter by several millimeters), and about six millimeters broad at the broadest place. The opercular ring is three millimeters from the animal pole (Fig. 5, *a*). Very rarely a second ring is found at about the same distance from the vegetal pole.

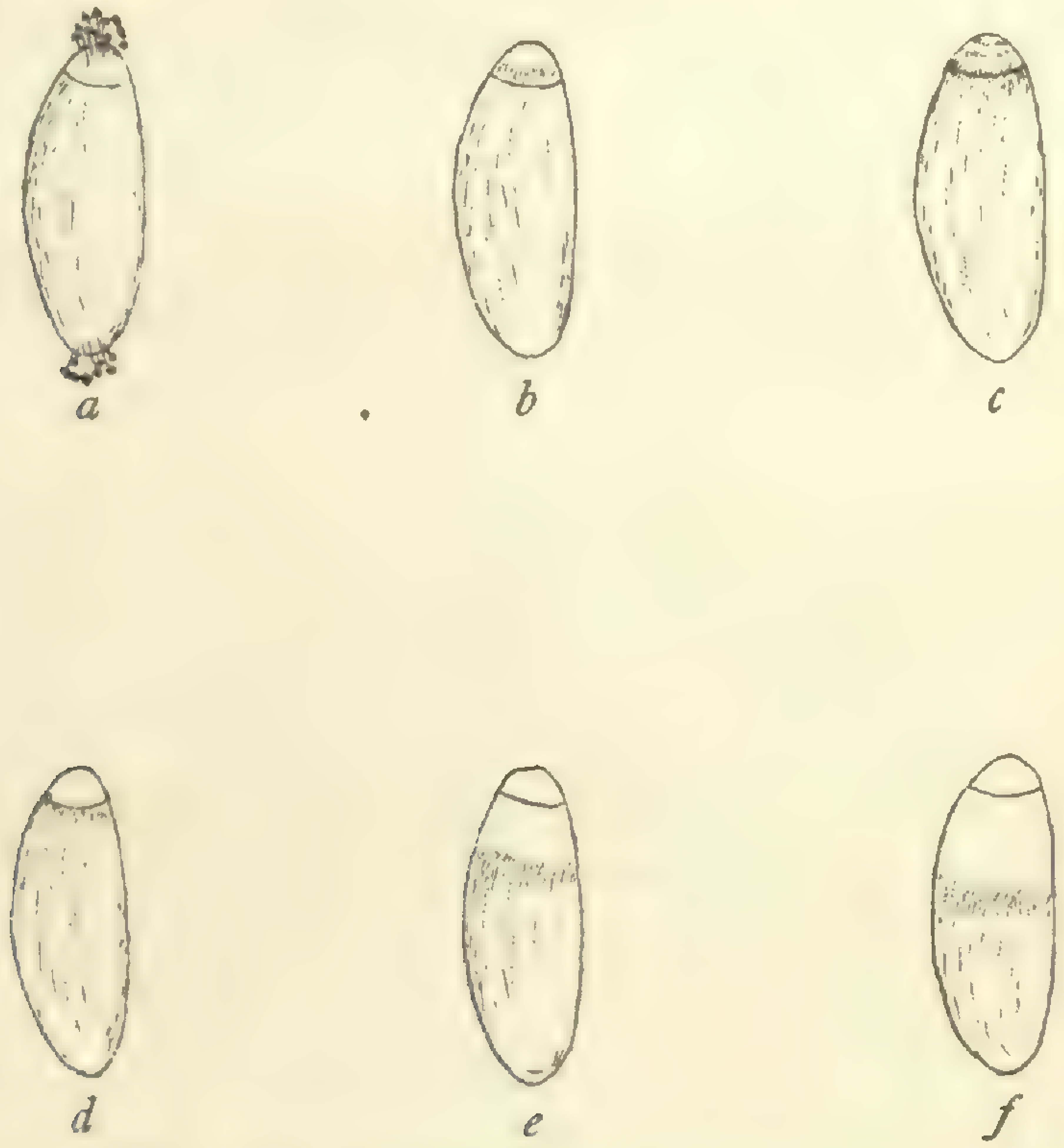


FIG. 5.—**Eggs in the early stages of development.** ***a*, fresh laid egg; *b*, the same egg with** the anchor filaments cut off, and showing protoplasmic disc at the animal pole; ***c*, three-**day egg, showing the terraces; *d*, at the beginning of the fourth day; *e*, the fifth day; *f*, the sixth day. Natural size.

Dean ('99) speaks of the egg being encased, when deposited, in two outer membranes, both of which are shed shortly after laying. Several eggs were brought me by the fisherman that had evidently been secured before they were ripe for oviposition. These eggs were identical with those, mentioned above, that I

had obtained from a hagfish which died in the aquarium. They were covered, anchor filaments and all, with a tough white membrane, translucent, but not transparent. When this was stripped off there was no second membrane inside, but instead, a thick jelly-like substance that filled in all the space between the egg-shell proper and the outer membrane. I do not hold with Dean that this outer membrane and jelly is shed shortly after laying, but think, instead, for two reasons, that the egg is freed from it before being deposited. The set of eggs in this condition taken from the dead fish, was left in the aquarium, and all but one were eaten before morning. That one, however, was left untouched. It had its outer membrane still on it, and remained in this condition. My second reason is, that the eggs normally laid in the aquarium, seven of which had been undisturbed, were, when I first saw them, entirely free from any such structure. They were in two groups, a group of four and a group of three, joined together by their anchor filaments and forming two parallel straight lines. There were no cast off membranes anywhere to be seen, and whatever might have happened to the jelly, the membrane could not have been dissolved by the salt water. Moreover, the eggs were joined by the anchor filaments, which could easily have happened if they were deposited free of membrane and jelly, but would have been impossible otherwise, as there was no force in the tank that could have changed the position of the eggs after they were deposited, or could have arranged them in regular groups. If the membranes were cast off after extrusion, what became of them? If they dissolved (and the one on the egg of the other set was neither dissolved nor cast off), how were the eggs pushed close enough together for their anchor filaments, previously separated by at least two thicknesses of membrane, to interlock?

I transferred the seven recently deposited eggs to a dish, in which was a constant flow of fresh salt water, in the hope that some of them might prove to be fertilized. The fresh eggs were a delicate, brilliant yellow in color with a white mass at the animal pole. I found them Tuesday morning, September 20th. Fig. 5, *a*, shows one in its normal state; *b* is the same egg without the anchor filaments, and shows the protoplasmic mass.

In the evening of the same day, two eggs, *a* and *b*, showed this protoplasmic mass extending halfway between the animal pole and the opercular ring. On the next day *a* had this mass extending two thirds of the way to the ring, while *b* was apparently unchanged. No changes had been noticed in any of the other eggs. Thursday showed no particular change in any of the eggs. On Saturday morning, the fourth day, *a* had a translucent cap, lighter in color than the rest of the egg, extending from the animal pole to one millimeter past the ring (Fig. 5, *d*), while in *b* the protoplasmic mass at the pole came two thirds of the way toward the ring, and was grouped in three distinct terraces (Fig. 5, *c*). The other eggs had merely the protoplasmic mass, coming halfway to the ring.

By three P. M. the same day, the cap of *a* had grown 1 mm. measuring 5 mm. from the pole to its edge at its deepest place. Before noon the next day it had grown 2 mm. more, measuring 7 mm. all told. Egg *b* had lost its terraces, and gained instead a cap, coming to within $\frac{1}{3}$ mm. of the ring, while a third egg, *c*, which had heretofore appeared quiescent, showed a marked terrace. One hour later the cap on *b* had passed the ring by $\frac{1}{3}$ mm. At this time *a* is represented by Fig. 5, *e*; *b* by Fig. 5, *d*; and *c* by Fig. 5, *c*.

Monday, the sixth day, at ten A. M., the cap on *a* was 9 mm. deep, and on *b*, 5 mm.; *c* was still in the terrace state, and terraces were showing faintly on *d*; *a* also had a tiny white dot, 1 to $\frac{1}{2}$ mm. below the ring, and in the middle of the flattened part of the egg. That same day at five P. M. the cap of *a* measured 10 mm. and the white speck was just the same, *b*'s cap was 6 mm. deep, the terraces of *c* and *d* were unchanged, and terraces were beginning to show on *e*; *f* and *g* were as they had been in the beginning. By measuring carefully morning and evening for several days I found that the average rate of growth of the cap after the terrace state was passed, was two millimeters in twenty-four hours, and that the time of highest rapidity was between ten A. M. and five P. M., as much space often being covered then as was covered between five P. M. and ten the next morning.

Tuesday, *a* and *b* were progressing at the usual rate of growth,

c had a cap reaching a little more than a millimeter past the ring, and *f*, in which I had not previously noticed any terraces, had a cap a trifle deeper than that of *c*. The caps in the earlier stages are very hard to detect, as the difference in translucency between them and the rest of the egg is very slight, and the shell somewhat opaque.

Wednesday morning at the end of the first week, *a*'s cap was 13 mm. deep, *b*'s 9 mm., *c*'s 7 mm., *f*'s 8 mm., while *d*, which had shown terraces almost as soon as *c*, lagged behind with a cap of only a little more than $4\frac{1}{2}$ mm.

By five P. M., *a*'s had grown 1 mm., *b* had not changed at all, while on the others the caps had grown 2 mm. each, twice the usual amount. That night, however, they all grew at the regular rate. Meantime, the white speck on *a* was no longer visible. On Friday, the tenth day, in addition to the usual increase in size of the cap, a very fine white line appeared on *c* a little below the ring, whose further history could not be traced.

On Monday, October third, at five P. M., not quite fourteen days after the eggs were laid, the blastopore of *a* was closed. Within a few days the blastopores of the other developing eggs closed also. Within this week, owing perhaps to very hot weather, the eggs died.

But they had lived long enough to confirm the idea of their exceedingly slow growth: fourteen days from the beginning of development to the closure of the blastopore, and no head elevation, or primitive streak showing in this time. In all eggs where the primitive streak shows, or where the young embryo does not extend the full length of the egg, there is a cap over the egg, that extends about one millimeter beyond the tail of the embryo. This second cap, however, is caused by changes in the yolk. With the appearance and growth of the mesoderm, the yolk near the embryo and immediately beneath the shell becomes spongy and full of vacuoles in which lymph and blood spaces are laid out. This gives this part of the yolk a whiter appearance than the rest and so forms a cap.

It is worthy of note that the five eggs that began to develop were supposedly all fertilized at the same time; nevertheless, there was a difference of from one to three days in the starting

of development, and only one started immediately. How shall we account for the uneven rates of growth noticed in one or two eggs afterwards, for instance on the day when *b* did not grow at all, and the others grew twice their usual daytime amount? What caused *f* to lie apparently quiescent for several days, then omit the terrace state, or cut it down to a ten or twelve hours at most, instead of the thirty-six to forty-eight it generally lasts and then growing with a leap, outstrip its brothers *c* and *d*, and finally even *b*? The eggs were all kept under identical conditions, and the most marked variations were in those in the same dish. It would seem impossible for external conditions to affect one without affecting all the others, yet here were decided variations in a process generally much more uniform.

BIBLIOGRAPHY.

AYERS, HOWARD.

'94. *Bdellostoma dombeyi*, Lac. *Biol. Lectures at Woods Holl, in Summer Session of 1903*. Ginn & Co., Boston.

AYERS, HOWARD, AND JACKSON, C. M.

:00. Morphology of the Myxinoidei. *Bull. of the University of Cincinnati*, October.

BEARD, J.

'92. Notes on Lampreys and Hags. *Anat. Anz.*, vol. 8, pp. 59–60.

CUNNINGHAM, J. T.

'87. The Reproduction of Myxine. *Zool. Anz.*, no. 256, pp. 390–392.

CUNNINGHAM, J. T.

'87a. On the Structure and Development of the Reproductive Elements in *Myxine glutinosa*. *Quart. Jour. Micr. Sci.*, vol. 27, pp. 49–76.

CUNNINGHAM, J. T.

'87b. The Reproductive Organs of Bdellostoma. *Trans. Roy. Soc. Edinburgh*, vol. 33, pp. 247–250.

DEAN, BASHFORD, (with others).

'97. The Columbia University Zoölogical Expedition of 1896. *Trans. N. Y. Acad. Sci.*, vol. 16.

DEAN, BASHFORD.

'99. On the Embryology of *Bdellostoma stouti*. *Festsch. 70ten Geburtstage von Carl von Küpffer.*

DEAN, BASHFORD.

:04. Notes on Japanese Myxinoides. *Jour. College of Sci., Imperial University, Tokyo*, vol. 19, art. 2.

HOWES, G. B.

'94. Biology in America. A Prospect. *Nature*, vol. 51.

MÜLLER, JOHANNES.

'34. Vergleichende Anatomie der Myxinoiden, der Cyclostomen mit durchbohrtem Gaumen. *Abh. k. Akad. Wissensch. Berlin*, 1834, pp. 65–340.

PUTNAM, F. W.

'73. Notes on the Genus Myxine and Genus Bdellostoma. *Proc. Boston Soc. Nat. Hist.*, vol. 16.

CINCINNATI, OHIO.
April, 1905.

NOTES ON THE GENITALIA OF LYMNÆA.

FRANK COLLINS BAKER.

INTRODUCTION.

WITH the exception of *Lymnæa megasoma* and *Lymnæa mighelsi*, nothing has been published on the genitalia of the American species of Lymnæa. Last fall the writer embraced the opportunity to dissect most of the common eastern Lymnæas, with some interesting results which are presented in the following paper.

In studying this subject it is eminently desirable that the material should be freshly killed and not alcoholic, as the latter condition causes portions of the genitalia to contract and otherwise lose their normal shape. Likewise in observing the male organ it is essential that it should be fully inverted, otherwise the form of the penis-sac and the length of the penis will be much modified, as shown by the accompanying cut (Fig. 1). The genitalia of the nine species examined are comparatively uniform, differing principally in the form of the prostate and in the length of the penis. The vagina and uterus also show some modifications.

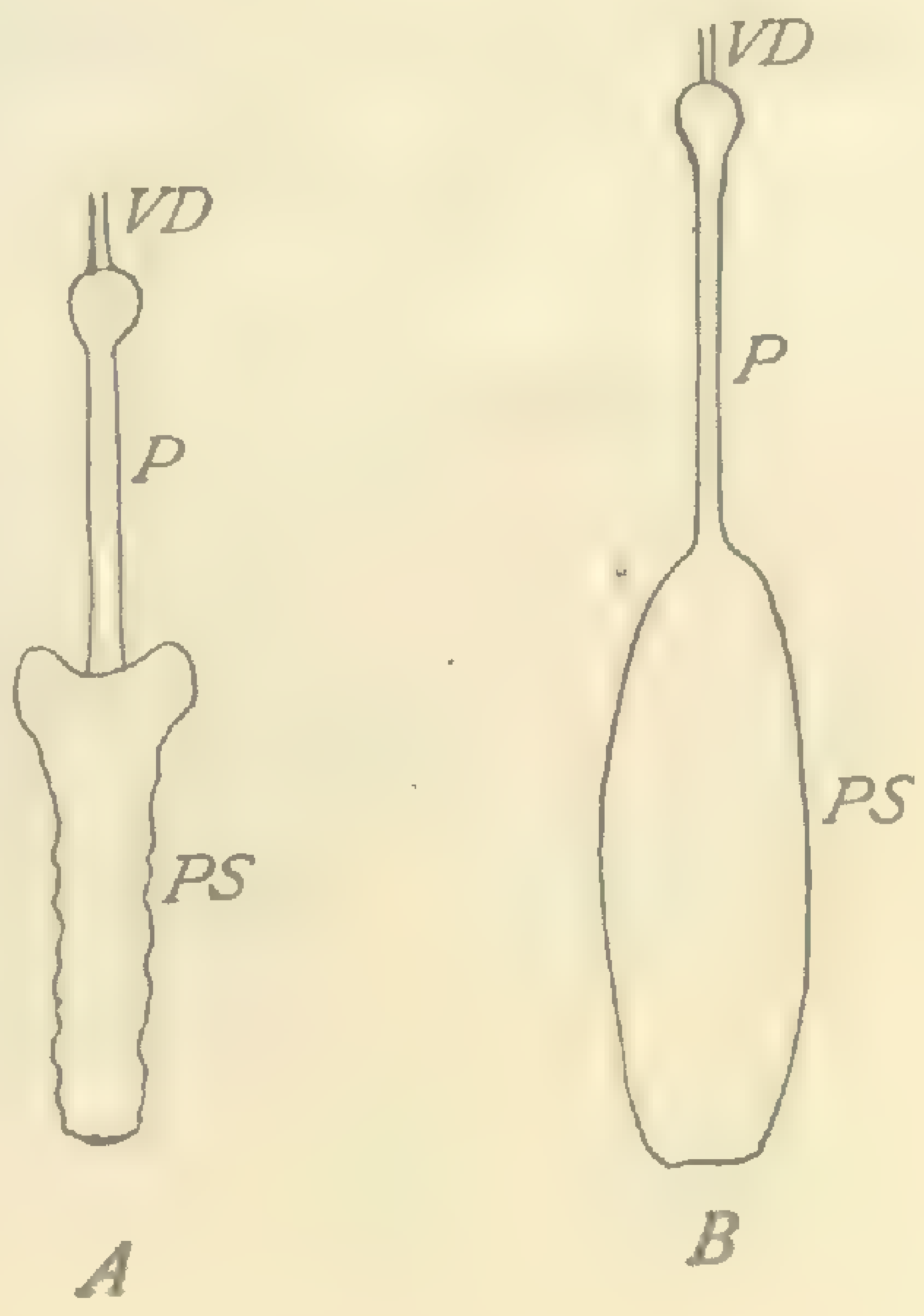


FIG. 1.—Male organs of Lymnæa. *a*, penis partly everted in penis-sac; *b*, fully inverted. Note the different shape of the penis-sac in the two conditions.

The material dissected was obtained from the following sources: *L. stagnalis appressa*, *stagnalis jugularis*, *elodes*, and *humilis* were collected in Braddock's Bay, Lake Ontario; *L. emarginata* and *catascopium* were collected

in Seneca Lake, N. Y.; *L. desidiosa* was obtained from Allen's Creek, N. Y.; *L reflexa* was obtained from Long Lake, near Millers, Indiana, and *L. auricularia* was secured in the greenhouse in Lincoln Park, Chicago. All but the last two were dissected in September.

In the figures the different parts of the genitalia are designated by the following letters: *al*, albuminiparous gland; *cm*,

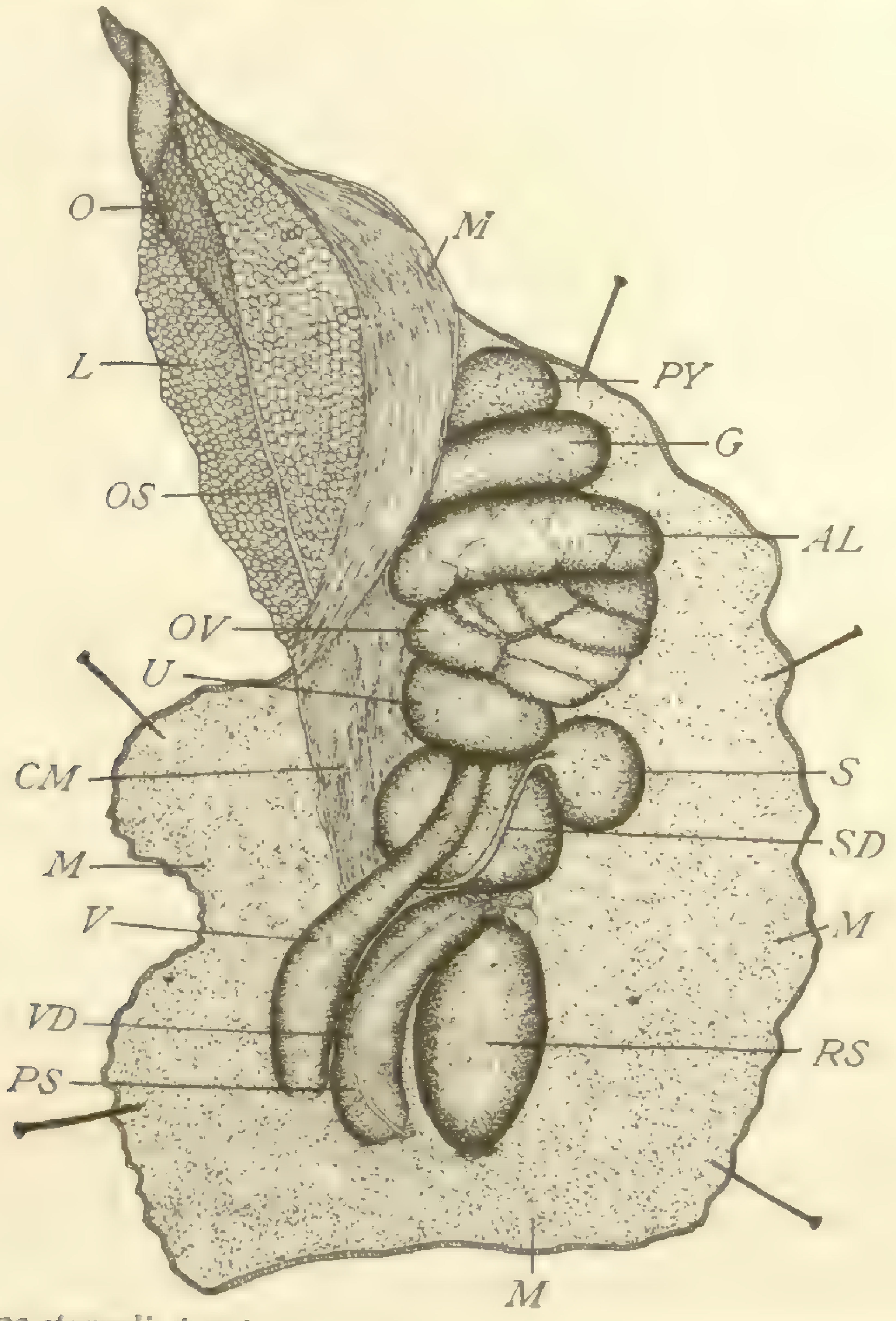


Fig. 2.—*Lymnæa stagnalis jugularis* opened from above, showing the reproductive organs in their natural position.

columella muscle; *fn*, nerves to female organs; *g*, gizzard; *l*, liver; *m*, mantle; *mn*, nerves to male organs; *o*, ovotestis; *ov*, oviduct; *os*, ovisperm or hemaphrodite duct; *p*, penis; *pd*, duct of prostate gland; *pr*, prostate gland; *ps*, penis-sac; *pmp*, penis protractor muscles; *pmr*, penis retractor muscle; *py*, pylorus; *rs*, radula sac; *s*, spermatheca or receptaculum seminis; *sd*, duct of spermatheca; *u*, uterus; *v*, vagina; *vd*, vas deferens.

The position of the genitalia is the same in all of the species

examined, the male and female organs opening by separate orifices, that of the former being behind the right tentacle and that of the latter at the base of the neck, not far from the pulmonary opening. The genitalia occupy the median portion of the body cavity and are the most conspicuous organs when the animal is opened from the back (Fig. 2). The female organs closely embrace the alimentary tract, stomach, and esophagus, the ovotestis being imbedded in the liver near the posterior part of the animal. The male organs lie to the right of the buccal sac, the vas deferens being coiled up between these two organs. The relations of the different organs cannot be made out until they are spread out and separated from each other.

Discussion of Species.

Lymnæa stagnalis appressa Say. (Figs. 3, 4.)

Male Organs.— Penis-sac very large, cylindrical, rather wide at the external opening and narrowing toward the distal end where the penis is attached. The penis is very short and rather thick, about one fourth the length of the penis-sac. There are three sets of protractor muscles on the penis-sac and two sets of retractor muscles. A large, thick muscle is inserted in the head of the penis at one end and is attached to one of the retractor muscles. The vas deferens is very long and extends from the penis to the base of the penis-sac where it is lost in the columella muscle, to appear again at the base of the vagina as the duct of the prostate gland, which is long and hair-like and enters the prostate in a rounded, bulbous-shaped organ, which gradually narrows until it enters the ovisperm duct.

Female Organs. — The vagina is a narrow, cylindrical organ about as long as the penis-sac. At the distal end it forms a large, rounded, more or less pyriform uterus, which narrows to form the oviduct, which is a tortuous, much folded organ, doubled upon itself several times. This organ narrows and unites with the ovisperm duct, which leads to the ovotestis or hermaphrodite gland, which is made up of rounded or lobulated follicles and is strongly attached to the liver. The albuminiparous gland

is very large. The receptaculum seminis is rather small, pyri-

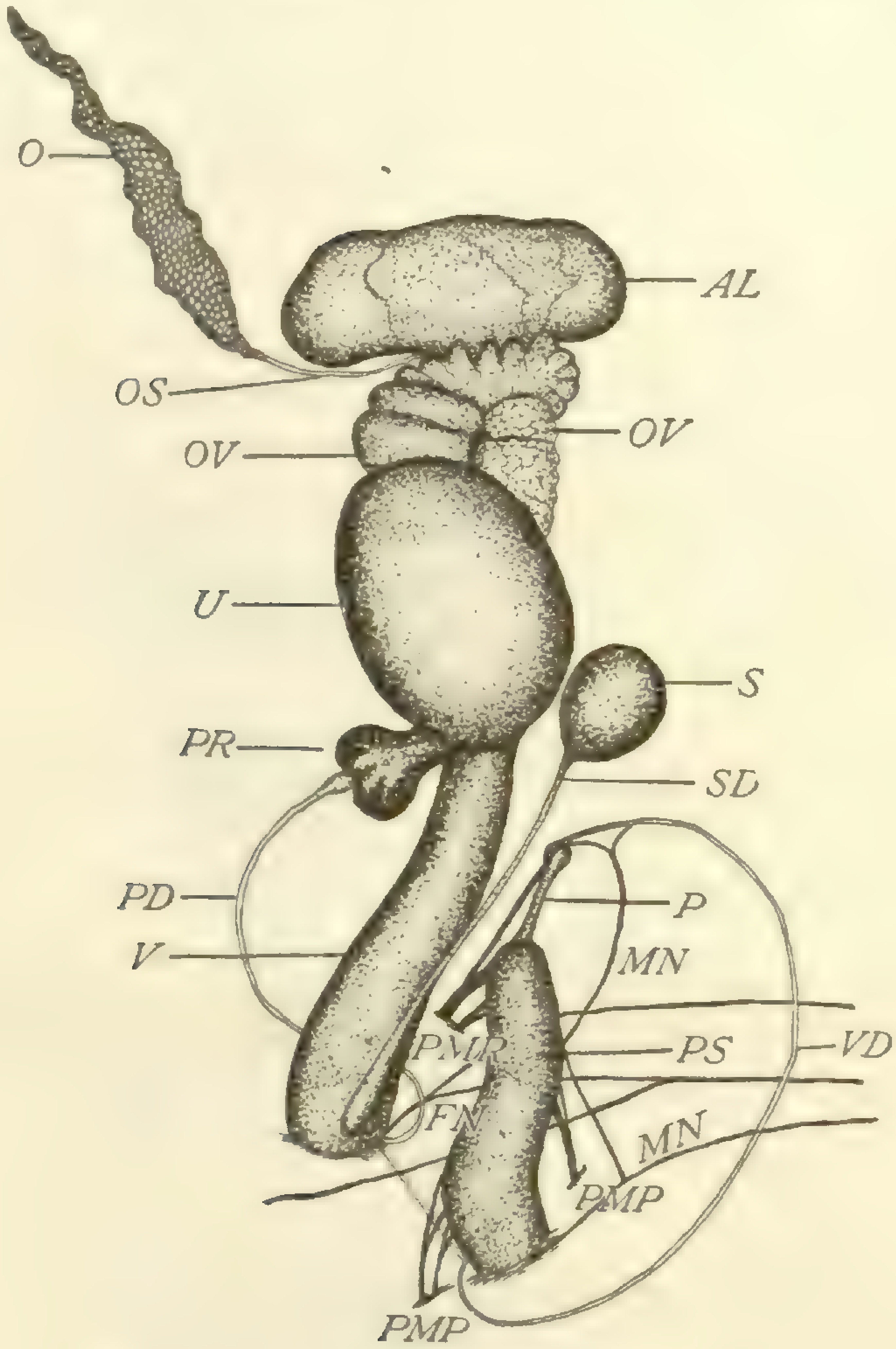


Fig. 3.—Genitalia of *Lymnæa palustris appressa.*

form, and is connected with the lower part of the vagina by a long, narrow duct. Both male and female genitalia are supplied with nerves, the former from the cerebral ganglion and the latter from the right visceral ganglion.

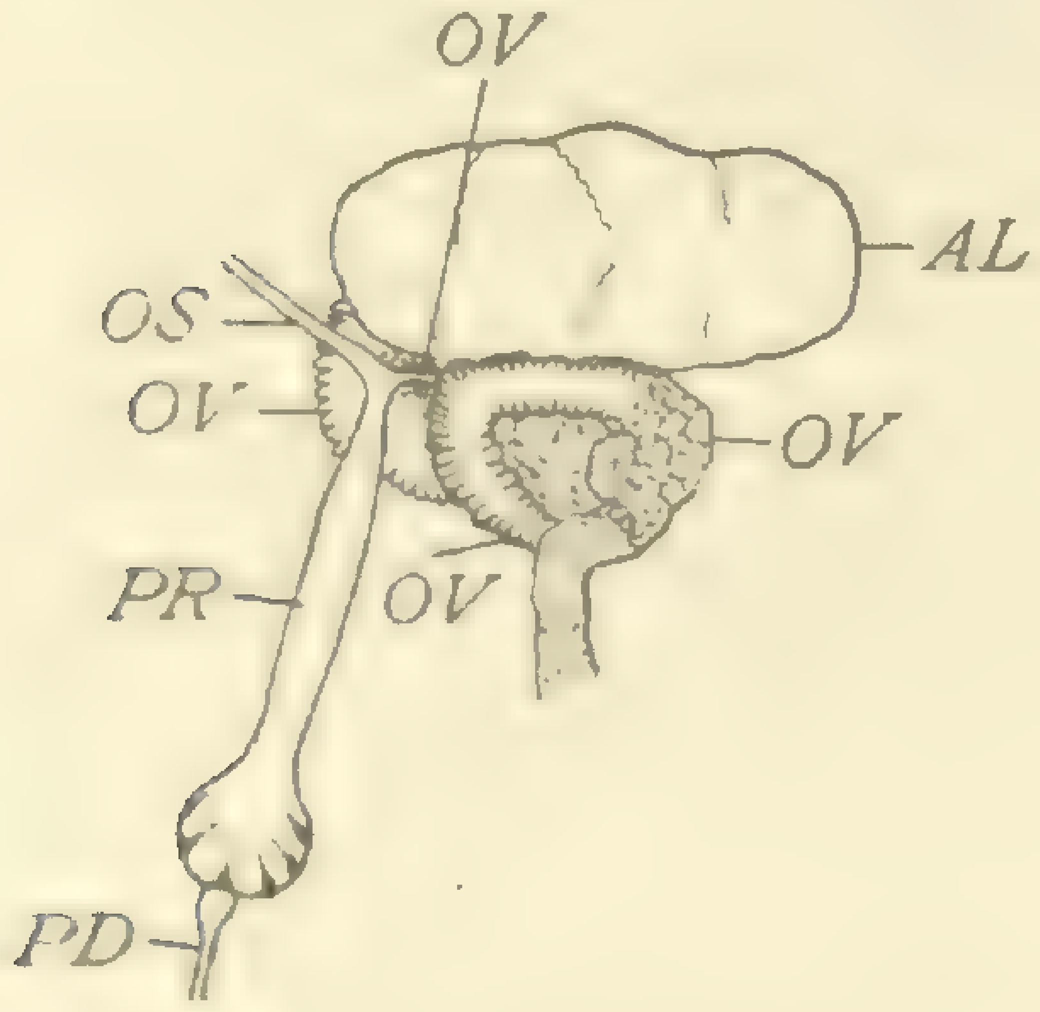


Fig. 4.—*Lymnæa palustris appressa,* showing position of oviduct, prostate, and ovisperm duct.

The organs are very brightly colored, the albuminiparous gland, oviduct, uterus, and receptaculum seminis being orange, the prostate orange shading into black at its insertion, the vagina blackish white, and the penis-sac flesh-colored. The ovotestis is white, as are also the muscles, vas deferens, and ducts of the female organs. The ganglia are bright pink or orange.

The true relations of the hermaphrodite portions of the genitalia cannot be understood until the organs are separated and spread out, when it is seen that the ovisperm duct divides into two branches, one branch forming the prostate, which cares for the spermatozoa, and the other branch forming the oviduct which carries the ova.

Lymnæa stagnalis jugularis Say.

The genitalia of this variety are in all respects like those of variety *appressa* excepting in color, the prostate being brownish yellow, the receptaculum seminis yellowish white, and the rest of the female organs yellowish and flesh-colored.

Compared with the European *stagnalis*, the American varieties seem to be almost identical. The figures in Keferstein (Taf. 103, Fig. 8) differ only in the form of the uterus, which is represented as more pyriform, and the bulbous part of the prostate is larger. The penis is not clearly defined in the figure. The figure in Prasch (Taf. 5, Fig. 7) is almost identical, the male organs being shown in much detail. The uterus is somewhat differently shaped but this may be due to a different point of view. There is nothing in the genitalia to separate the varieties of *stagnalis*.

Lymnæa palustris Müller (= *elodes* Say). (Fig. 5.)

Male Organs. — The penis is almost as long as the penis-sac and is very slender. The penis-sac is rather long, cylindrical, and of large diameter. There are two large, wide, ribbon-like retractors attached to the penis-sac and one muscle from the head of the penis to the posterior retractor muscle. Protractor muscles similar to those of *stagnalis*. Vas deferens long and thread-like. Prostate duct very fine; prostate thick, cylindrical, connected with the ovisperm duct as in *stagnalis*.

Female Organs.— Vagina long, cylindrical, of narrow diameter, enlarging to form a large, thick, pyriform uterus which narrows to form the much folded oviduct, which in turn narrows to form the ovisperm duct. Albuminiparous gland large. Receptacu-

lum seminis very large and globular, its duct very fine, enlarging somewhat at the point of insertion near the opening of the vagina. Ovotestis and nerves as in *stagnalis*.

The colors of the organs are: albuminiparous gland and uterus bright yellow, receptaculum seminis and prostate yellowish, penis-sac blackish, muscles, penis, vas deferens, and nerves whitish or flesh-colored.

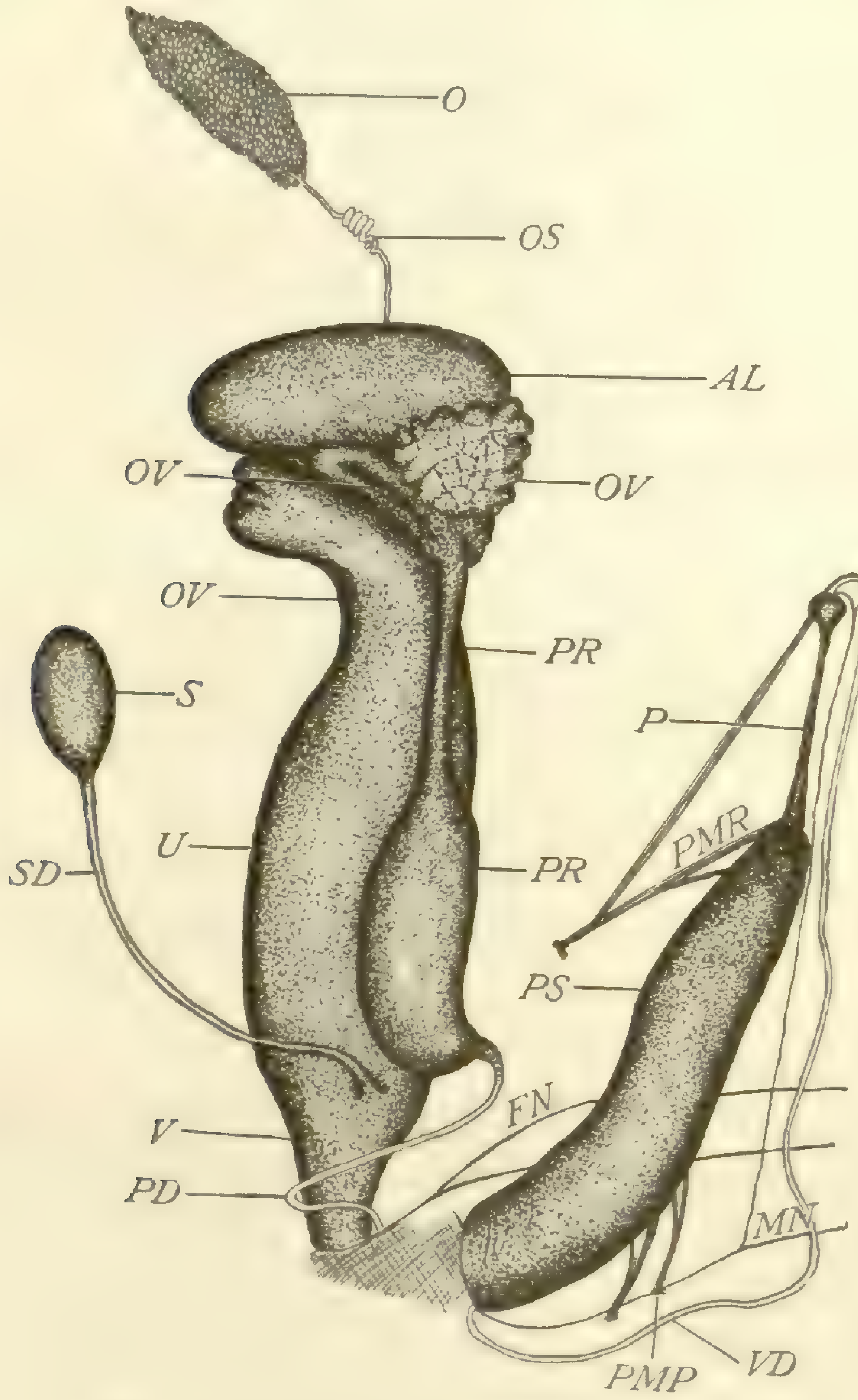


Fig. 5.—Genitalia of *Lymnæa palustris* (=*elodes*).

Palustris differs from *stagnalis* in the greater length of the penis, has a larger receptaculum seminis, a more pear-shaped uterus, and the proximal end of the prostate is pyriform, not bulbous.

Lymnæa reflexa Say.

The genitalia of this species seem to agree in all essential characteristics with those of *palustris*. The penis-sac has but one retractor muscle while the penis has the long retractor inserted in this muscle as in *palustris*.

Lymnæa emarginata Say. (Figs. 6, 7.)

Male Organs.—Penis and penis-sac as in *palustris* and *reflexa*. A single penis-sac retractor muscle in which the penis retractor

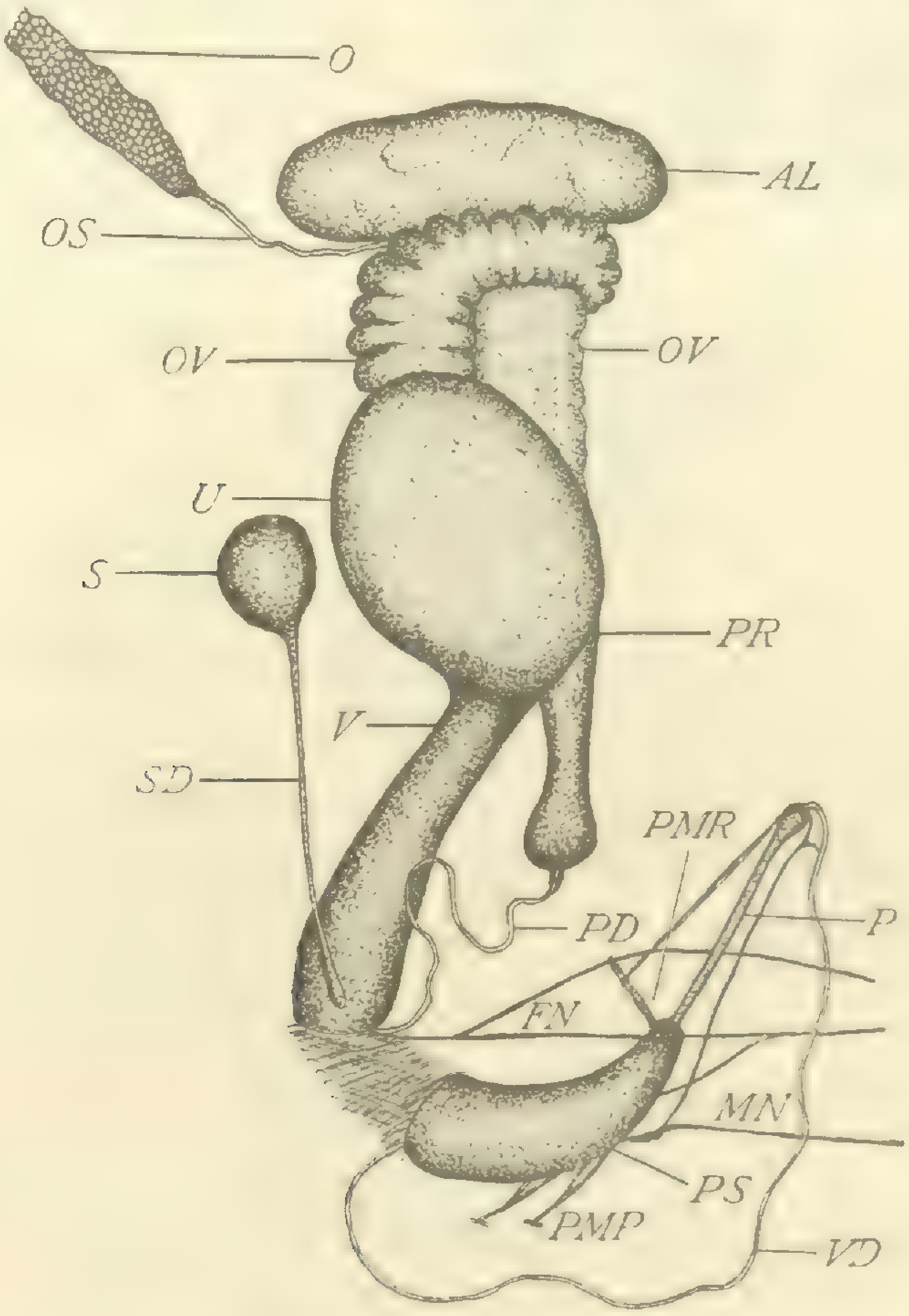


FIG. 6.—Genitalia of *Lymnæa emarginata*.

is inserted. Prostate cylindrical, of large diameter, with a somewhat bulbous proximal extremity, which narrows behind and then enlarges, to contract again before connecting with the ovisperm duct.

Female Organs.—The vagina is rather short and of large

diameter; the uterus is somewhat egg-shaped and very large; oviduct large and much folded. Receptaculum seminis globular, small, its duct very fine, inserted near the opening of the vagina. Albuminiparous gland large.

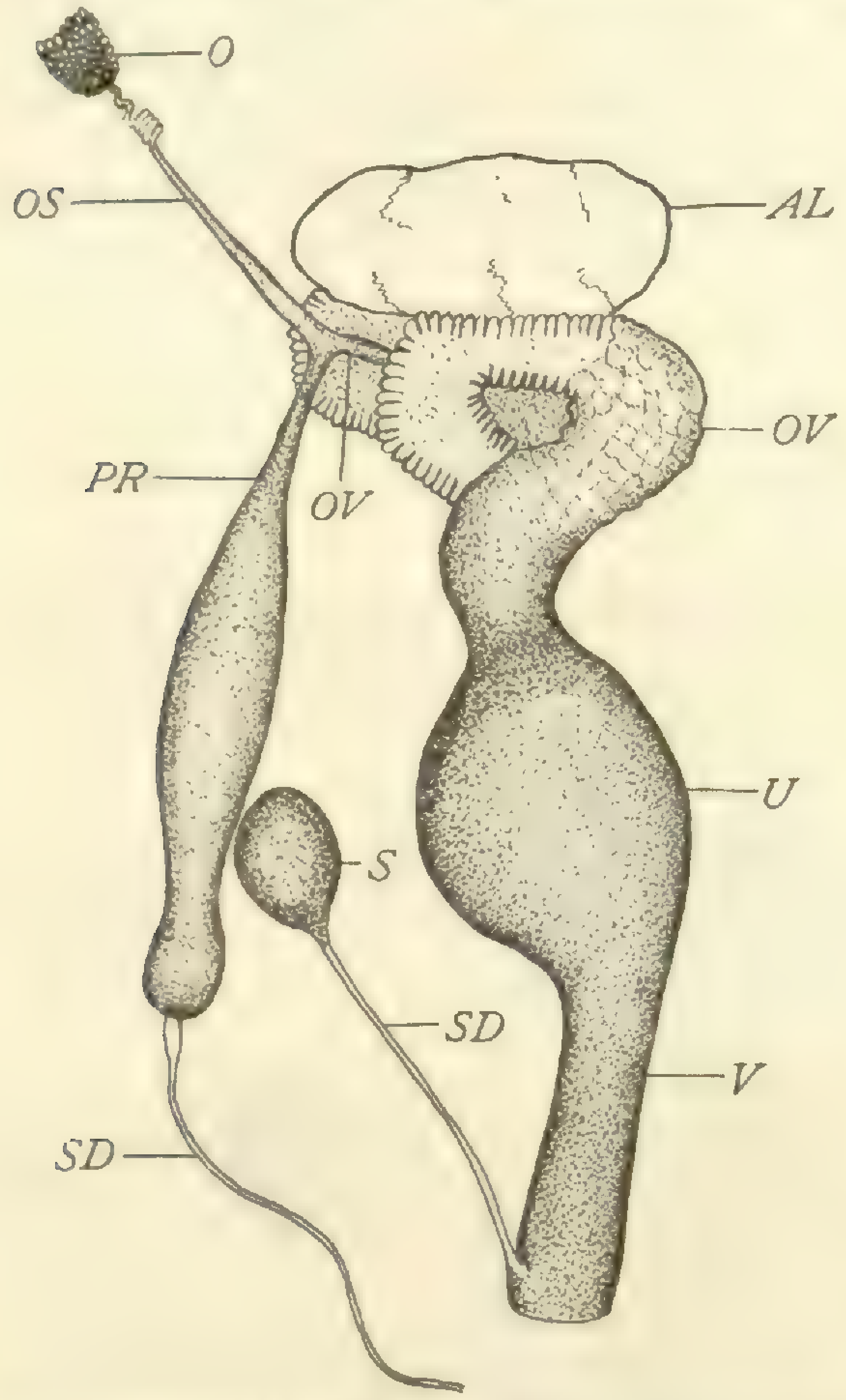


FIG. 7.—Genitalia of *Lymnæa emarginata*, the organs separated to show their relations to each other. Note the division of the ovisperm duct to form the oviduct and prostate.

The organs are colored as follows: oviduct orange, male genitalia blackish white, the rest of the organs flesh-colored.

The genitalia of *emarginata* differ from those of *palustris* in having a more bulbous-shaped uterus, a smaller receptaculum seminis and a more cylindrical prostate, which terminates in a somewhat bulbous enlargement resembling that of *stagnalis*. The muscles of the penis and penis-sac are like those of *palustris*.

Lymnæa desidiosa Say. (Fig. 8.)

Male Organs.—Similar to those of *emarginata*. The prostate is whitish and is irregularly fusiform, tapering at both extremities. Muscles and their insertions as in *emarginata* and *reflexa*.

Female Organs.—The vagina is very short and the uterus is large and long and pyriform in shape. The receptaculum seminis is globular in form and larger in proportion than that of *emarginata*.

FIG. 8.—Prostate of *Lymnæa desidiosa*.

Lymnæa humilis Say.

The genitalia of this small species appear in all respects like those of *desidiosa.* The receptaculum seminis is a rich salmon color, the prostate is whitish, and the rest of the organs are yellowish white.

Lymnæa mighelsi Binney.[1] (Fig. 9.)

Male Organs.— Penis-sac cylindrical, very long and of large diameter. Penis long and slender, half the length of the penis-

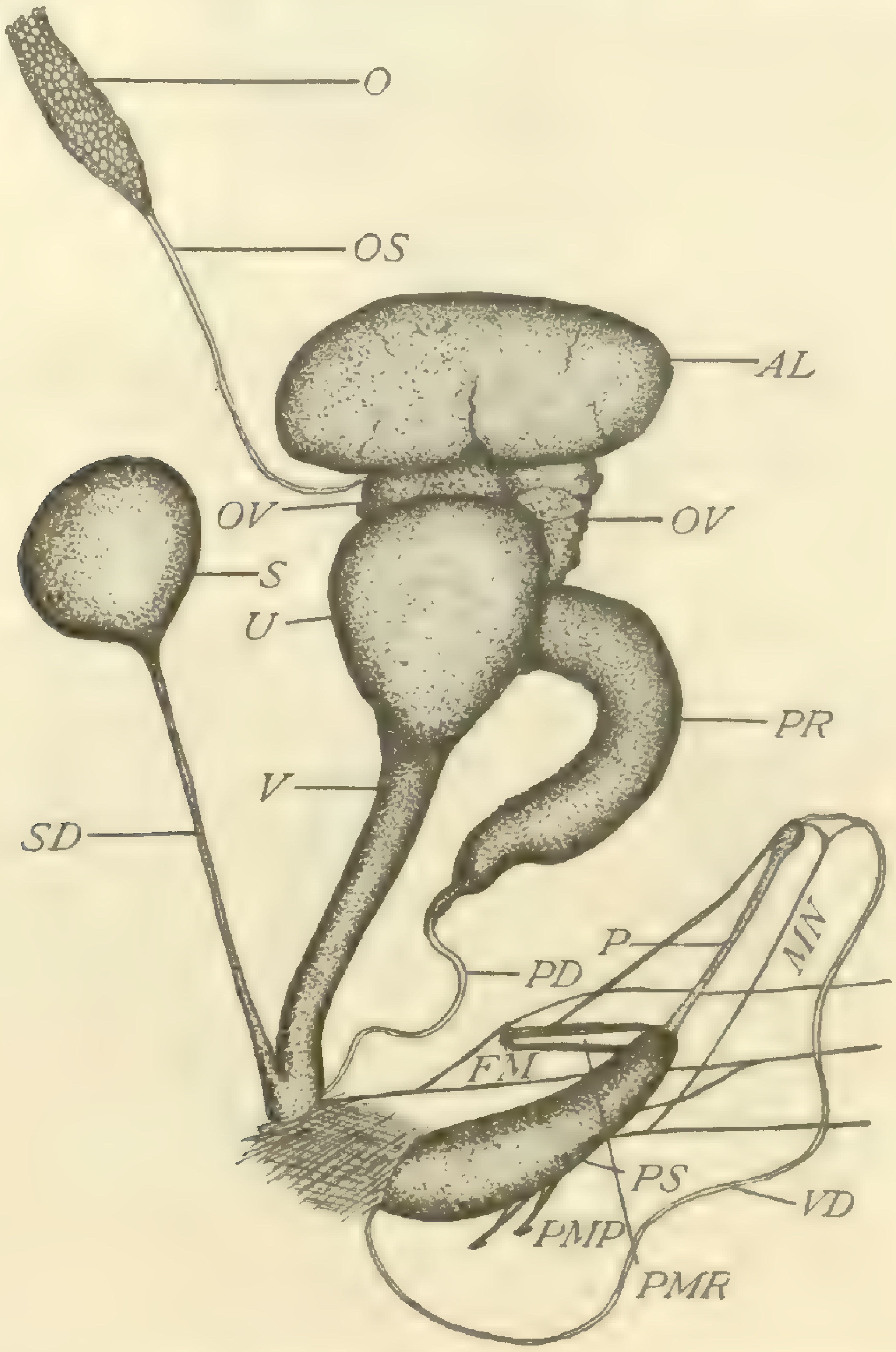


FIG. 9.—Genitalia of *Lymnæa mighelsi.* The male organs are drawn somewhat nearer the female organs than in nature.

sac. There is a single stout, ribbon-like retractor muscle attached

[1] The description of *mighelsi* is modified and corrected from that published in *Bull. Chicago Acad. Sci.*, vol. 2, no. 3, p. 202.

to the distal end of the penis-sac; and the penis muscle, which is attached to the head of the penis, is inserted in this muscle near its attachment to the columella muscle. Vas deferens and innervation as in the other species described. The prostate is large and cylindrical at its junction with the prostate duct, but becomes very long and narrow at its posterior portion and again narrows as it unites with the ovisperm duct.

Female Organs.— The ovotestis is made up of the usual lobulated follicles. The ovisperm duct is rather long; the oviduct is a much lobed organ, rather long and of large diameter; it enlarges to form a long, cylindrical uterus which suddenly contracts to form the vagina. The receptaculum seminis is small, elongate-ovate in form and connects with the vagina rather high up by a narrow duct. The albuminiparous gland is not large and is of the usual form. The innervation is as in the other species described.

The organs are colored as follows: penis and penis-sac yellowish, prostate yellowish or amber-colored, ovotestis yellowish, albuminiparous gland greenish, receptaculum seminis pearly white, and the other organs yellowish. The muscles are white in color.

The genitalia of *mighelsi* differ from those of all the other species described in the form of the uterus, which is long and cylindrical while the vagina is short and wide. The prostate is also differently shaped. The penis-sac is very long and wide while the penis is about half its length. It is evident from a study of the genitalia of *mighelsi* and *emarginata* that the former is specifically distinct from the latter. The penis is shorter, the oviduct is differently shaped, as well as the prostate. The shells also exhibit differential characters.

Lymnæa catascopium Say.

Male Organs.— In all respects like those of *emarginata.* The prostate is also like that of *emarginata.* The receptaculum seminis is more pear-shaped. The uterus is not so swollen, the distinction between vagina and uterus not being very marked, and the two organs form a long, somewhat cylindrical sac.

Lymnæa auricularia Linné. (Fig. 10.)

Male Organs.— Penis-sac cylindrical, long, of large diameter. Penis very long and slender, exceeding the penis-sac in length. Penis retractor single, attached to the distal end of the penis-sac by a double connection. Prostate in the form of an elongated, inverted pear, narrowed at either end where it joins the

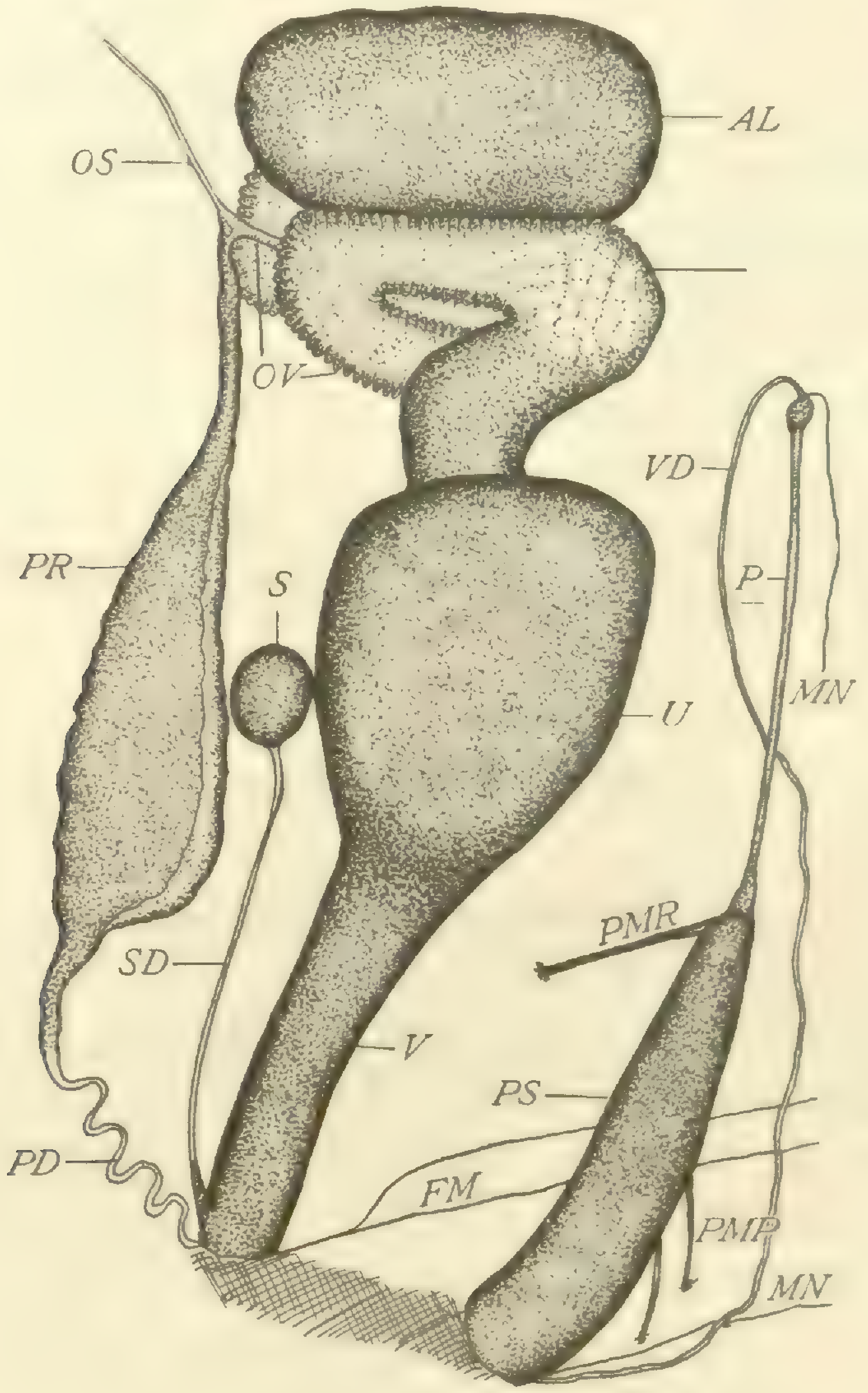


FIG. 10.— Genitalia of *Lymnæa auricularia*.

ovisperm duct and prostate duct. The prostate is dark gray in color with the exception of a narrow band of white on the border.

Female Organs. — The ovotestis is of the usual form. The ovisperm duct is of medium length. The oviduct is a much

lobed organ, rather long and wide; it abruptly enlarges to form a bulbous uterus, which narrows to form a rather long, wide vagina. The receptaculum seminis is small and spherical and connects with the vagina near its opening by a very long, narrow duct. The albuminiparous gland is very large. Nerves as in the other species. The uterus is yellowish, the albuminiparous gland is yellowish brown, the vagina is blackish white, the receptaculum is bright red and the other organs are flesh-colored.

The genitalia of *auricularia* do not resemble those of any other species very closely. The penis is longer than in any other species and the receptaculum is smaller. The uterus is more swollen and of a different shape. The prostate resembles that of both *elodes* and *mighelsi*.

Moquin-Tandon's figure in the *Histoire Naturelle des Mollusques Terrestres et Fluviatiles de France* shows the organs of different shape and position, but this may be due to viewing them in a different position and without separating the organs.

Lymnæa megasoma Say.

No specimens of this species have been obtainable for dissection. Wetherby's description and figure in *Jour. Cincinnati Soc. Nat. Hist.*, vol. 2, p. 95, show the penis to be rather wide and shorter than the penis-sac. The receptaculum seminis is ovate-pyriform. The other organs are not very clearly shown.

Comparisons.

The question has presented itself to the writer as to whether the genitalia of Lymnæa will afford sufficiently stable data upon which to base systematic groups or subgenera. In the land shells these organs furnish, in many cases, excellent characters for generic and even family divisions. It is possible that the examination of a large number of species might produce tangible

results, but the data presented in this paper seem hardly sufficient for this purpose, although some interesting features are brought out.

In the foregoing remarks, nine species and two varieties have been discussed. In comparing the genitalia of these eleven forms, several notable facts are at once apparent. The length of the penis as compared with the penis-sac is striking. The following table shows these relations (see Fig. 11):—

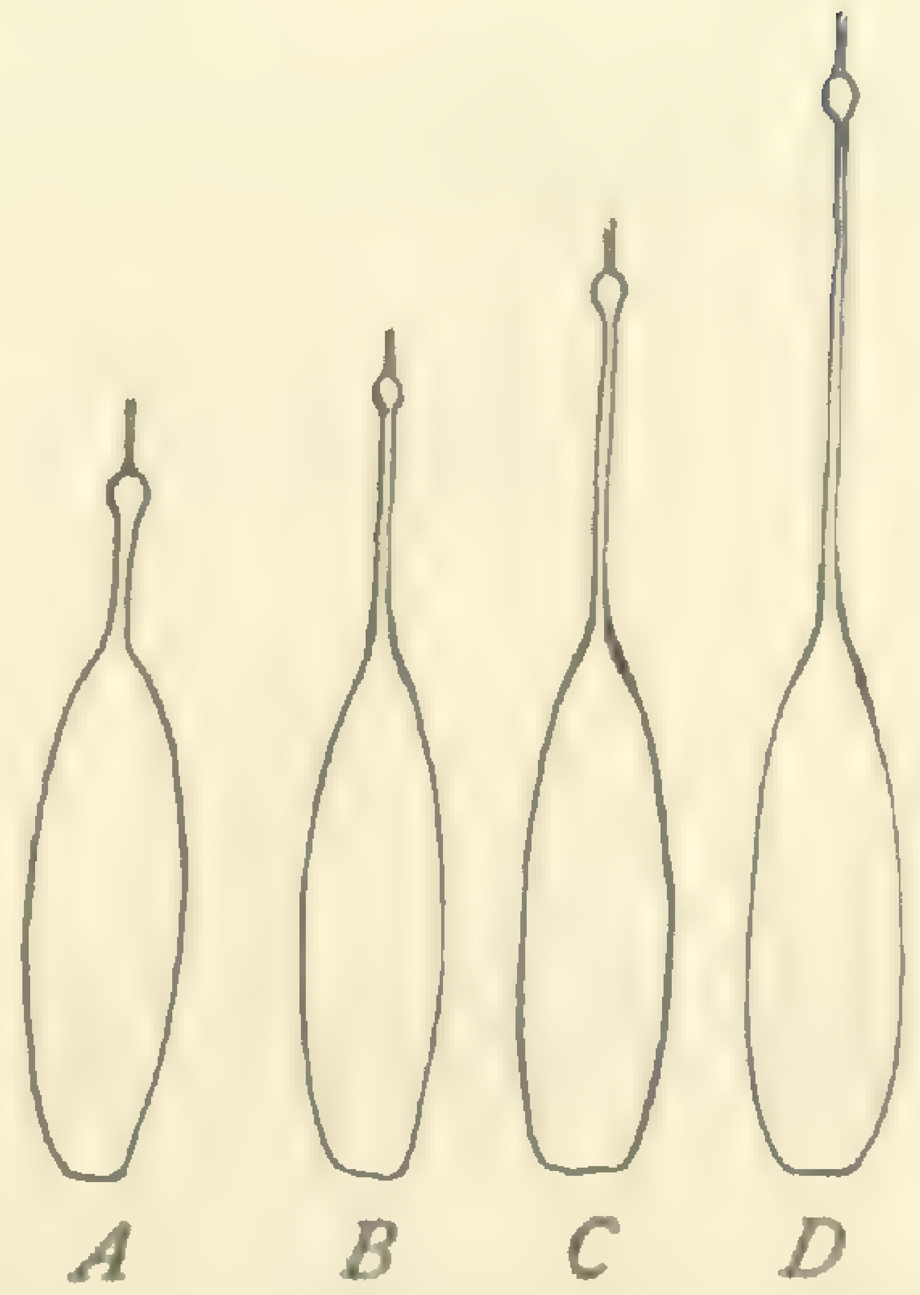


FIG. 11.—Comparison of the length of the penis with the penis-sac. *a*, *stagnalis*; *b*, *mighelsi*; *c*, *palustris*; *d*; *auricularia*.

Comparative Length of Penis and Penis-sac.

One fourth length.	One half length.	Three fourths length.	Longer.
appressa	*mighelsi*	*emarginata*	*auricularia*
jugularis		*palustris*	
		reflexa	
		catascopium	
		desidiosa	
		humilis	
		megasoma ?	

There seems to be some difference in the number of penis retractor muscles attached to the penis-sac. In *stagnalis* and *palustris* there are two, with a muscle extending from these muscles to the penis. In *emarginata, mighelsi, auricularia, reflexa, desidiosa, humilis,* and *catascopium* there is but one retractor, in which is inserted the penis muscle. In *auricularia* there is but one penis-sac retractor and no muscle is attached to the penis. The prostate shows some differences, being fusiform in some species (*viz.*, *desidiosa, auricularia, mighelsi,* etc.) and cylindrical with an enlarged bulbous termination in the other species (*viz.*, *stagnalis, emarginata*). The uterus also varies from ovate to pyriform.

The colors of some of the organs, especially of the receptaculum, are striking. This latter organ is colored as follows in the different species : —

appressa, orange.	*desidiosa*, salmon.
jugularis, yellowish.	*mighelsi*, pearly white.
reflexa, yellowish.	*humilis*, salmon.
emarginata, flesh-colored.	*auricularia*, bright red.

The receptaculum seminis varies in several of the species, both in size and in shape. In *palustris* it is of extraordinary size while in *auricularia* it is very small.

While the characters of the genitalia do not seem to aid materially in the establishment of higher groups they do aid very largely in the separation of the species. The writer hopes to be able to examine all of the American species in the near future.

BIBLIOGRAPHY.[1]

BAKER, FRANK C.

:00. The Gross Anatomy of *Limnæa emarginata* Say, var. *mighelsi* Binney. *Bull. Chicago Acad. Sci.*, vol. 2, pp. 191–211.

BAUDELOT.

'63. Recherches sur l'appareil générateur des mollusques Gastéropodes. *Ann. des Sci. Nat., Zool.*, ser. 4, vol. 19, pp. 135–222, 268–294.

KEFERSTEIN, WILHELM.

'62–'66. Bronn's Klassen und Ordnungen der Weichthiere ; Malacozoa. Leipzig und Heidelberg.

LACAZE-DUTHIERS, HENRI.

'72. Du systeme nerveux des mollusques et d'un nouvel organe d'innervation. *Arch. Zool. Exp.*, ser. 1, vol. 1, pp. 437–500.

MOQUIN-TANDON, A.

'55. Histoire naturelle des mollusques terrestres et fluviatiles de France. Paris, 2 volumes and atlas.

MOQUIN-TANDON, A.

'61. Observations sur les prostates des Gastéropodes androgynes. *Jour. de Conch.*, vol. 9, pp. 1–19.

[1] The list of works on this subject is not exhaustive.

Prasch, A.

'**43**. Neben das Geschlechtssystem und die Harn bereitenden Organe einiger Zwitterschnecken. *Arch. für Naturges.*, 1843, pt. 1, pp. 71–104.

Wagner, Rudolph.

'**35**. Bemerkungen über die Geschlechtstheile der Schnecken. *Arch. für Naturges.*, vol. 1, p. 368.

Wetherby, A. G.

'**79**. Notes on some New or Little Known North American Limnæidæ. *Jour. Cincinnati Soc. Nat. Hist.*, vol. 2, p. 95.

Whitfield, R. P.

'**81**. Description of *Limnæa* (*Bulimnæa*) *megasoma* Say, with an Account of Changes produced in the Offspring by Unfavorable Conditions of Life. *Bull. Amer. Mus. Nat. Hist.*, vol. 1, pp. 29–37.

Chicago Academy of Sciences.

NOTES AND LITERATURE.

BOTANY.

Porter's Catalogue of the Bryophyta and Pteridophyta of Pennsylvania [1] is an attractive volume of 66 pages. It is a list in which localities and collectors are indicated after the name of each species, and includes about 542 species and varieties. The catalogue was compiled by Dr. Porter, the mosses revised by Mrs. Britton, and the whole edited by Dr. Small. The names of such well known collectors as James, Austin, Muhlenberg, Porter, Rau, Garber, Burnett, Small, and Mrs. Britton appear many times throughout the catalogue and add much to its value. The arrangement of families and genera conforms very closely with that in Limpricht's *Die Laubmoose.* Some exceptions to this statement will be noticed, *e. g.*, Hylocomium is placed between Brachythecium and Eurhynchium.

Some of the most conspicuous changes in familiar generic names are the following: Mollia Schrank for Gymnostomum (partly), Gymnostomum Hedw. for Pottia, Weissia Ehrh. for Ulota, Leersia Hedw. for Encalypta, Astrophyllum Neck. for Mnium, Arrhenopterum Hedw. for Aulacomnium (partly), Mnium Dill. for Aulacomnium (partly), Webera Ehrh. for Diphyscium, Eleutera Beauv. for Neckera, and Forsstromia Lindb. for Leptodon.

The catalogue is well bound in a very neat cloth cover and is clearly printed on good paper with a dead surface. It is absolutely indispensable to all students of the Pennsylvania Archegoniates and even the more general student should not neglect placing it in his library.

J. F. C.

Notes.— The seventh fascicle of the Genera Siphonogamarum of Dalla Torre and Harms, following the Engler sequence of families, has reached Liabum, of the Compositæ — which bears the serial number 9371.

Vol. 8, part 5, section 2, of the *Reports of the Princeton University Expeditions to Patagonia*, by Macloskie, deals with the phanerogamic families Santalaceæ to Cactaceæ, and bears date of January 2.

[1] Porter, T. C. *Catalogue of the Bryophyta and Pteridophyta of Pennsylvania.* Boston, Ginn & Co., 1904. 8vo., 66 pp. $1.00.

The new edition of the *Prodromus Floræ Batavæ*, in course of publication by the Nederlandsche Botanische Vereeniging, reaches the end of Apetalæ in the third part of volume 1, recently issued.

A second part of de Wildeman's studies of Congo plants has been issued from Brussels.

Vol. 5, part 1, of Wood's Natal Plants, dealing with grasses, is dated December, 1904.

"The Luquillo Forest Reserve, Porto Rico," is the title of *Bulletin no. 54* of the Bureau of Forestry, U. S. Department of Agriculture, by Gifford.

A paper by Shimek on the flora of the St. Peter sandstone in Winneshiek County, Iowa, is published in vol. 5, no. 4, of the *Bulletin* from the laboratories of natural history of the State University of Iowa.

A colored plate of *Shortia galecifolia* appears in *Flora and Sylva* for January.

A colored plate of *Yucca guatemalensis* is published in *Curtis's Botanical Magazine* of February.

An account of *Musa textilis*, by Edwards, forms *Farmers' Bulletin No. 12* of the Philippine Bureau of Agriculture.

A paper on the grasses of Walter's "Flora Caroliniana," by Hitchcock, has been separately printed from the *Sixteenth Report of the Missouri Botanical Garden.*

Dulichium spathoceum is said by Hartz, in Engler's *Botanische Jahrbücher* of February 28, to occur in Danish interglacial bogs.

An account of *Welwitschia mirabilis*, with original photographic illustrations taken in its native home, is published by Baum in *Die Gartenwelt* of March 18.

Professor Greene publishes a number of new species of Aragallus in the *Proceedings of the Biological Society of Washington* of January 20.

An account of the British Hieracia, recently published by W. R. Linton, includes 124 species with numerous minor forms.

Habit and bark photograms of *Fraxinus pennsylvanica* are published by Rothrock in *Forest Leaves* for February.

The 20th Heft of Engler's "Das Pflanzenreich" consists of a treatment of Zingiberaceæ, by Schumann.

No. 20 of the *Bulletin de l'Institut Botanique de Buitenzorg* consists of a paper on Javan Zingiberaceæ, by Valeton.

An epitome of the British Indian species of Impatiens, by Sir Joseph Hooker, is begun in vol. 4, no. 1, of the *Records of the Botanical Survey of India*.

Spegazzini records 140 cacti, of which many are described as new, from the Argentine Republic in a paper separately issued from vol. 11 of the *Anales del Museo Nacional de Buenos Aires* under the title "Cactacearum Platensium Tentamen."

A paper on Cephalotus by Hamilton, with other interesting botanical matter, is contained in vol. 29 of the *Proceedings of the Linnean Society of New South Wales*.

Some West American red cherries are described by Greene in the *Proceedings of the Biological Society of Washington* of February 21.

A paper on the comparative anatomy and phylogeny of Abietineæ, by Jeffrey, forms vol. 6, no. 1, of the *Memoirs of the Boston Society of Natural History*.

Dr. Moore's Philadelphia address on "Applied Botany and its Dependence upon Scientific Research" is separately issued from *Science* of March 3.

Dr. Galloway's recent report as chief of the Bureau of Plant Industry shows in a concise way the varied investigations being carried on by this branch of the national Department of Agriculture. Sixty-one percent of the 490 employees of the Bureau are said to be engaged in scientific and related work.

A popular account of henequen farming in Yucatan is to be found in *Modern Mexico* of February.

A colored plate of the rose "Madame Norbert Levavasseur," which has been rechristened "Baby Rambler" in this country, is published in *Gartenflora* of January 1.

A monograph of American varieties of lettuce, by W. W. Tracy, Jr., forms *Bulletin no. 69* of the Bureau of Plant Industry of the U. S. Department of Agriculture.

An instructive winter tree-study bulletin, for young people, is contained in the February–March number of the Cornell *Home Nature-Study Course*.

Some old British tree trunks are figured in vol. 22, part 3, of the *Transactions and Proceedings of the Botanical Society of Edinburgh.*

The deformations of woody plants sometimes called "witches' brooms" are discussed by Solereder in the *Naturwissenschaftliche Zeitschrift für Land- und Forstwirtschaft* for January.

An account of graft-hybridization or symbiosis in Vitis is given by Voss in *Landwirtschaftliche Jahrbücher*, vol. 33, part 6.

The effect of self-pollination in Papilionaceæ is discussed by Kirchner in the January *Naturwissenschaftliche Zeitschrift für Land- und Forstwirtschaft.*

Seaside ecology in Ceylon finds exposition by Tansley and Fritsch in *The New Phytologist* of January 30.

An account of the Mandragora of the ancients in folk-lore and medicine, by Randolph, forms vol. 40, no. 12, of the *Proceedings of the American Academy of Arts and Sciences.*

The chemistry of indigo is considered by Hazenwinkel and Wilbrink, in no. 73 of the *Mededeelingen uit 's Lands Plantentuin*, from the Buitenzorg Garden.

A popular account of the seedless, coreless, and blossomless apples is given by Thomas in *The American Inventor* of April 1.

An interesting series of weed studies, by Waldron, constitutes *Bulletin no. 62* of the North Dakota Experiment Station.

Von Schrenk reports on experiments in the chemical treatment of railroad ties as a means of checking fungus growth, in *Bulletin no. 51* of the Bureau of Forestry, U. S. Department of Agriculture.

Professor Macbride's Philadelphia address, on The Alamogordo Desert, is distributed in separate form.

That the raphides of Agave, like those of *Scilla maritima*, Narcissus, etc., may cause severe irritation of the skin is noted in the *Gardeners' Chronicle* of March 11.

Roth's "Die Europäischen Laubmoose" has reached a conclusion in the recently issued 11th Lieferung.

An important contribution to the bryology of the Azores is published by Cardot in the *Bulletin de l'Herbier Boissier* of February 28.

The supposed influence of fungi in causing the formation of tubers in Solanum has been further tested, with inconclusive results, by

Jumelle, whose paper appears in the *Revue Générale de Botanique* of February 15.

Fusicladium pirinum, and its effect on the pear, form the subject of *Bulletin no. 163* of the Agricultural Experiment Station of California, by Smith.

Bæodromus, a coleosporioid rust of Senecio, is described by Arthur in *Annales Mycologici* of February, which also contains other papers on American fungi.

The Discomycetes of Iowa form the subject of a paper by Seaver in vol. 5, no. 4, of the *Bulletin* from the laboratories of natural history of the State University of Iowa.

An analysis of the species of Phragmidium, by Dietel, has been published in recent numbers of *Hedwigia.*

Atkinson's 1893 account of "Carnation Diseases" is reprinted in *The American Florist* of January.

A discussion of soil bacteria and nitrogen assimilation, by Chester, forms *Bulletin no. 66* of the Delaware College Agricultural Experiment Station.

A paper by Moore on soil inoculation for legumes, with reports upon the successful use of artificial cultures by practical farmers, constitutes *Bulletin no. 71* of the Bureau of Plant Industry of the U. S. Department of Agriculture.

A further discussion of copper as an algicide and disinfectant in water supplies is given by Moore and Kellerman in *Bulletin no. 76* of the Bureau of Plant Industry, U. S. Department of Agriculture.

A catalogue of the shrubs in the Vilmorin Garden, by Maurice L. de Vilmorin and D. Bois, with descriptions of new or recently introduced species, has recently been issued from the *Librairie Agricole* of Paris.

An illustrated account of the desert laboratory at Tucson is given by Lloyd in the *Popular Science Monthly* for February.

A Herkomer portrait of Sir Joseph Hooker is reproduced in halftone in *The Gardeners' Chronicle* of January 7.

A note on the work of Philippi, with portrait, is published by Hicken in the *Anales de da Sociedad Científica Argentina* of October last.

A portrait of B. L. Robinson is published in the *Popular Science Monthly* for February.

The Journals. — With January, a new journal, *The Nature Study Review*, appears under the editorship of Professor M. A. Bigelow with a strong advisory board. It contains much of interest to the teaching botanist.

The Iowa Naturalist is a new venture launched by T. J. Fitzpatrick from Iowa City.

An attractive new periodical, *The Garden Magazine*, is begun by Doubleday, Page & Co., the first number issued being for February.

Botanical Gazette, January: — True and Oglevee, "Effect of the Presence of Insoluble Substances on the Toxic Action of Poisons"; Livingston, "Relation of Soils to Natural Vegetation in Roscommon and Crawford Counties, Mich."; Elmer, "New and Noteworthy Western Plants"; Olive, "Morphology of *Monascus purpureus*"; Davis, "Fertilization in the Saprolegniales," and "The Sexual Organs and Sporophyte Generation of the Rhodophyceæ."

Botanical Gazette, February: — Barnes, "The Theory of Respiration"; Whitford, "The Forests of the Flathead Valley, Montana — I"; Holm, "Studies in the Gramineæ — VIII, *Munroa squarrosa*"; Chamberlain, "Alternation of Generations in Animals from a Botanical Standpoint"; Ganong, "New Precision-Appliances for Use in Plant Physiology — II."

Botanical Gazette, March: — Coulter and Land, "Gametophytes and Embryo of *Torreya taxifolia*"; Olsson-Seffer, "The Principles of Phytogeographic Nomenclature"; Whitford, "The Forests of the Flathead Valley, Montana — II"; Arthur, "Terminology of the Spore Structures in the Uredinales."

Muhlenbergia, no. 6. — Heller, "Western Species, New and Old — IV."

The Bryologist, March: — Best, "A Lesson in Systematic Bryology"; Fink, "How to Collect and Study Lichens"; Holzinger, "Some Recently Described North American Polytrichs"; Haynes, "Notes on a Colony of Hepatics found Associated on a Dead Fungus"; Crockett, "*Rhacomitrium heterostichum gracilescens.*"

Bulletin of the Torrey Botanical Club, December: — Emerson, "Notes on the Blackening of *Baptisia tinctoria*"; Rydberg, "Studies

on the Rocky Mountain Flora — XIII"; Maxon, "A New Asplenium from Mexico."

Bulletin of the Torrey Botanical Club, January: — Livingston, "Chemical Stimulation of a Green Alga"; Arthur, "Amphispores of the Grass and Sedge Rusts"; Berry, "Additions to the Fossil Flora from Cliffwood, N. J."

Bulletin of the Torrey Botanical Club, February: — Spalding, E. S., "Mechanical Adjustment of the Suaharo (*Cereus giganteus*) to Varying Quantities of Stored Water"; Horne, "A New Species of Lembosia"; Maxon, "On the Names of three Jamaican Species of Polypodium"; Peck, "New Species of Fungi"; Murrill, "The Polyporaceæ of North America — X"; Harper, "Further Observations on Taxodium."

The Fern Bulletin, January: — Harper, "The Fern Flora of Georgia"; Davenport, "A New Type of Aneimia"; Hill, "*Equisetum scirpoides* in Illinois"; Van Hook, "Illinois Ferns near Lake Michigan."

Journal of Mycology, January: — Morgan, "*Sphæria calva*"; Seaver, "A New Species of Sphærosoma"; Arthur, "Sydow's Monographia Uredinarum, with Notes upon American Species"; Memminger, "*Agaricus amygdalinus*"; Kellerman and Ricker, "New Genera of Fungi published since the year 1900 [My. to X., with index]"; Kellerman, "Uredineous Infection Experiments in 1904"; Kellerman, "Elementary Mycology (continued)"; Kellerman, "Ohio Fungi, Fascicle X. List of Species and Hosts."

Journal of the New York Botanical Garden, January: — Nash, "Botanical Exploration of the Inagua Islands, Bahamas."

Journal of the New York Botanical Garden, February: — MacDougal, "Studies in Organic Evolution."

Journal of the New York Botanical Garden, March: — Hollick, "A Recent Discovery of Amber on Staten Island"; Nash, "The Flowering of *Nolina texana*."

The Ohio Naturalist, January: — Schaffner, "The Life Cycle of a Heterosporous Pteridophyte"; Gleason, "Notes from the Ohio State Herbarium — II"; Schaffner, "Mat Plants"; Schaffner, "Plants with Nodding Tips"; Riddle, "Brush Lake Algæ"; Scholl, "Key to the Ohio Hickories in the Winter Condition"; Cotton, "Key to Ohio Ashes in the Winter Condition"; Schaffner, "Key to Ohio Poplars in the Winter Condition."

The Ohio Naturalist, February: — Schaffner, "Key to the Genera of Ohio Woody Plants in the Winter Condition"; York, "The Hibernacula of Ohio Water Plants"; Schaffner, M., "Key to the Ohio Sumacs in the Winter Condition."

The Ohio Naturalist, March: — Wacker, "Ecological Notes on Ohio Pteridophytes"; Flory, "Key to the Ohio Maples in the Winter Condition"; Schaffner, "The Classification of Plants — I"; Schaffner, "*Lycopodium porophilum* in Ohio"; Schaffner, "The Struggle for Life on a certain Sandbar"; Riddle, "Notes on the Morphology of Philotria"; Tillman, "Ohio Plants with Tendrils"; Schaffner, "Key to Ohio Walnuts Based on Twig Characters."

The Plant World, December: — Safford, "Extracts from the Notebook of a Naturalist on the Island of Guam — XXV"; Blanchard, "Millspaugh's Blackberry."

The Plant World, January: — Bayley Balfour, "Physiological Drought in Relation to Gardening"; Brackett, "A Summer in the Tropics"; Watterson, "An Unusual Begonia"; Mansfield, "A Curious White Oak."

The Plant World, February: — Underwood, "A Glimpse at Early Botanical Literature"; Brackett, "A Summer in the Tropics (conclusion)"; Pammel, "Notes on some Plants of Northeastern Iowa"; Schneck, "Fasciation in the Cherry"; G[ager], "The Protection of Winter Buds."

Torreya, January: — MacDougal, "Discontinuous Variation and the Origin of Species"; Nash, "A Paspalum New to the West Indies"; Vail, "*Onagra grandiflora*, a Species to be included in the North American Flora"; Britton, "*Carex Underwoodii*, sp. nov."; Clendennin, "Twin Pine Embryos."

Torreya, February: — Shull, "Galtonian Regression in the 'Pure Line'"; Spalding, V. M., "Soil Water in Relation to Transpiration"; Murrill, "A Key to the Stipitate Polyporaceæ of Temperate North America — I"; Berry, "A Palm from the Mid-Cretaceous"; Britton, "*Galactia Curtissii* sp. nov."; Sumstine, "*Panæolus acidus* sp. nov."

Torreya, March: — Underwood, "The Early Writers on Ferns and their Collections — IV"; Clendenin, "Other Freaks of Peas"; Murrill, "A Key to the Stipitate Polyporaceæ of Temperate North America — II"; Britton, "*Jacquinia Curtissii* sp. nov."; Cockerell, "New Binomials in an Index."

Rhodora, January: — Brainerd, "Notes on New England Violets — II"; Fernald, "A Peculiar Variety of *Drosera rotundifolia*"; Dewey, "Identity of Prickly Lettuce"; Fernald, "*Ledum palustre* var. *dilatatum* on Mt. Katahdin"; Parlin, "Further Notes on *Arabis lævigata* and *Asplenium Trichomanes* in Maine"; Leavitt, "On Translocation of Characters in Plants"; Bartlett, "*Arenaria macrophylla* in Connecticut"; Robinson, "A Connecticut Station for *Lycopodium Selago*."

Rhodora, February: — Leavitt, "On Translocation of Characters in Plants (continued)"; Fernald, "A New Arabis from Rimouski County, Quebec"; Churchill, "Preliminary Lists of New England Plants — XVII"; Clark, "White Form of *Sabbatia chloroides*"; Beattie, "Remarks on Rhode Island Plants."

Rhodora, March: — Ganong, "On Balls of Vegetable Matter from Sandy Shores"; Fernald, "An Undescribed Northern Comandra"; Hall, "Vegetative Reproduction of *Spiranthes cernua*"; Bartlett, "A New Juncus of the Group Poiophylli"; Evans, "Notes on New England Hepaticæ — III"; and Robinson, "A well marked Species of Sparganium."

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AMERICAN NATURALIST.

Vol. XXXIX. *October, 1905.* No. 466.

A PECULIAR VARIATION OF *TEREBRATALIA TRANSVERSA* SOWERBY.

H. W. SHIMER.

This specimen (Figs. 2–5) of this very variable species differs from the type as figured by Davidson (Fig. 1) in its more elongate form, thicker valves, obscurity of plications, and less development of the mesial sinus in the brachial valve.[1] Aside from its normal variation the specimen is remarkable for its extremely rugose surface due to the great inequality in the development of growth lines and also for the greatly abraded umbo of the pedicle valve. This abrasion is so great that it brings to view the unfilled cavity behind the buttress supporting the teeth which shows as a rounded hole, through which a bristle can be passed, on each side of the pedicle opening.

Dall, after an examination of this specimen, wrote us that it is "an unusually worn and deformed specimen which has been crowded by its fellows so as to grow out of shape and worn by rocking on its pedicle until at least one quarter of an inch of shell has been removed." In reference to the two holes above

[1] For other figures and variations of this species see "A Monograph on Recent Brachiopoda" by Davidson, *Trans. Linn. Soc. London*, ser. 2, vol. 4, and *Amer. Journ. Conch.*, vol. 6, pl. 6.

mentioned he suggested that between the shell wall and the buttress which supports the hinge in the dorsal valve there is a cavity. With the growth of the shell and the buttress this cavity is prolonged ; at times it is filled in part with shelly matter and at others it persists as a tube running up with the curve of the umbo, one on each side of the pseudodeltidium. If these tubes remain empty and the umbo is sufficiently abraded, they will appear on the surface of the shell as two little holes. An abrasion to this extent is very unusual ; the nearest approach to it noticed outside of this specimen was in *Terebratula harlani* Morton where the former cavities though filled with shelly growth, yet showed faintly where weathered.

This specimen and two other pedicle valves of the same species were collected by Professor W. O. Crosby of Massachusetts Institute of Technology in the summer of 1904; they were found on the beach at high tide at Kayak Village on Wingham Island, Controller Bay, Alaska. They are now in the collection of the Boston Society of Natural History, catalogue numbers 449 and 450.

The writer is indebted to Professor W. H. Dall of the United States National Museum and Professor Charles Schuchert of Yale University for the identification of this peculiar form.

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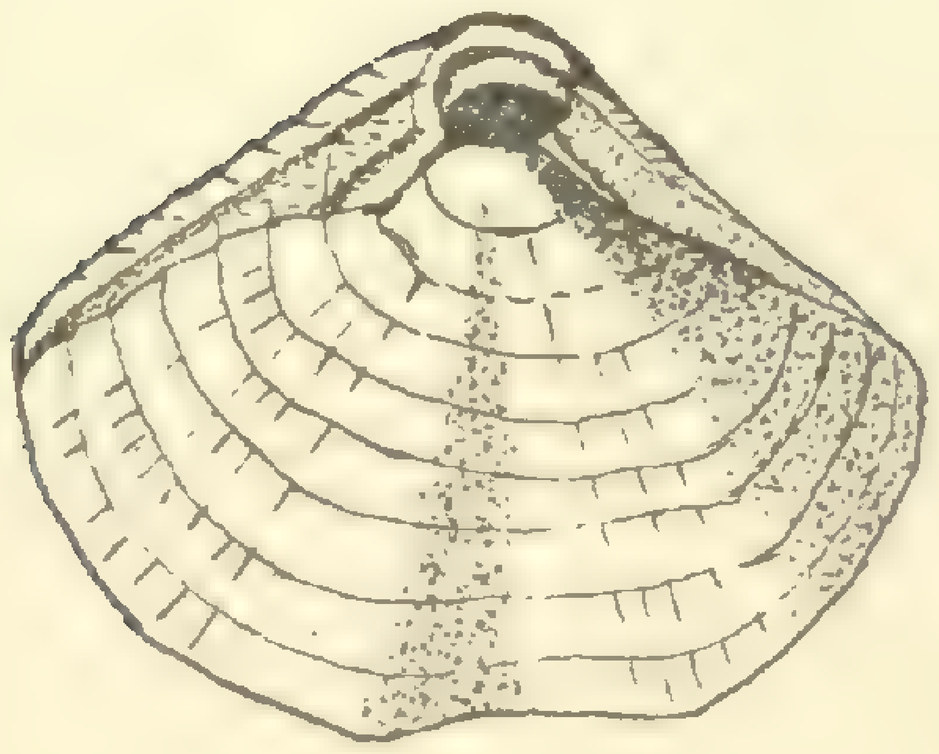

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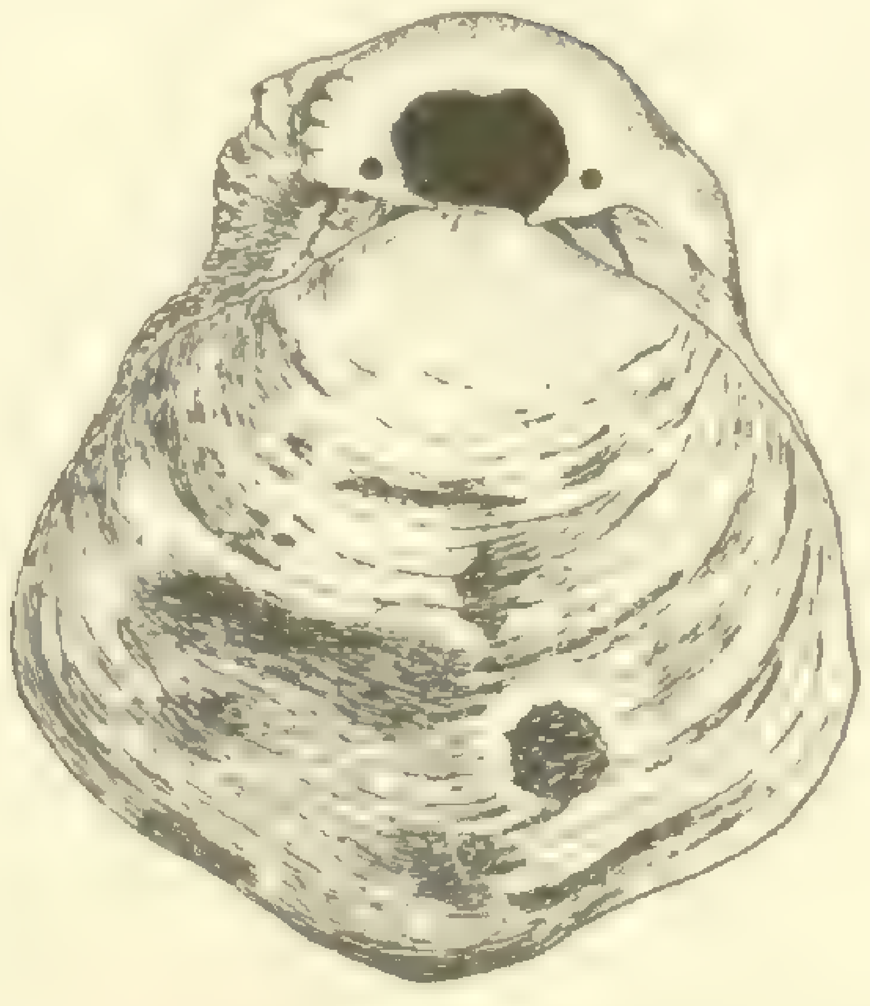

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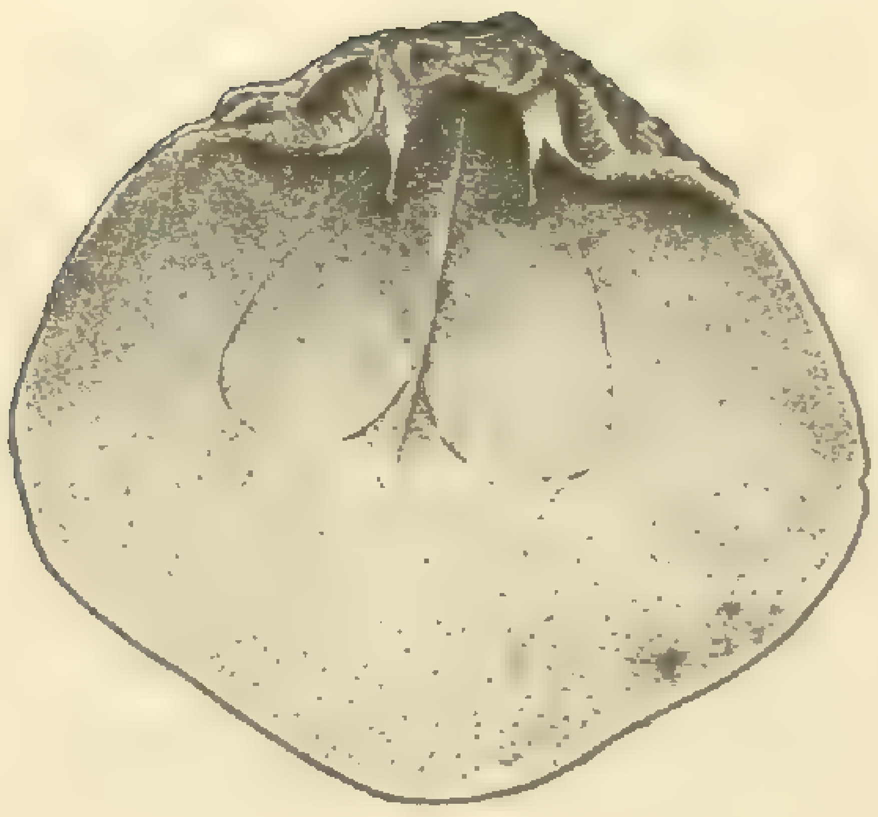

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PLATE I.

FIG. 1 — The type specimen of *Terebratalia transversa* Sowerby. Reproduced from pl. 16, fig. 6, in "A Monograph on Recent Brachiopoda," Davidson, *Trans. Linn. Soc London*, ser. 2, vol. 4.

FIG. 2.— Brachial view of a specimen of the same species from Wingham Island, Alaska, showing the greatly abraded umbo and the two small holes of the pedicle valve. Natural size. The muscular impressions are much more faintly marked than the figures indicate.

FIG. 3.— Side view of specimen seen in Fig. 2, showing the great irregularity in the growth of the shell. Natural size.

FIG. 4.— Interior of brachial valve of specimen seen in Fig. 2, showing the large cardinal process and the large dental sockets. Natural size.

FIG. 5.— Interior of pedicle valve of same specimen showing the heavy character of the shell about the umbo and the large teeth. Natural size.

STUDIES ON THE PLANT CELL.—VIII.[1]

BRADLEY MOORE DAVIS.

Section VI. Comparative Morphology and Physiology of the Plant Cell.

We shall devote this section to the discussion of a number of topics some of which have received brief mention in the preceding papers of the series but with other subjects will now be considered in some detail. The material will be treated under the following five headings: —

1. The simplest types of plant cells.
2. Comparisons of the structures of some higher types of plant cell with simpler conditions.
3. Some apparent tendencies in the evolution of mitotic phenomena.
4. The essential structures of the plant cell and their behavior in ontogeny.
5. The balance of nuclear and cytoplasmic activities in the plant cell.

1. The Simplest Types of Plant Cells.

There are three groups of plants which are conspicuous for the simplicity of their cell structure. They are: the Cyanophyceæ (blue-green algæ), Schizomycetes (bacteria), and the Saccharomycetes (yeasts). All three groups have received much attention and there has accumulated an extensive literature which we shall not attempt to treat in detail, since it has been handled very fully by the specialists in these subjects. We shall, however, present the most important conclusions and

[1] This paper concludes the series of studies on the plant cell. The author has a number of complete sets of reprints of this and the earlier sections. Enquiries may be addressed to Professor Bradley M. Davis, University of Chicago.

try to give the present status of investigations in these most difficult subjects.

Cyanophyceæ (*Blue-green Algæ*).— The most recent and comprehensive papers on the cell structure of the Cyanophyceæ are by Fischer ('97), Macallum ('99), Hegler (:01), Bütschli (:02), Kohl (:03), Zacharias (:00, :03), and Olive (:04). Olive gives an especially clear analysis of the situation in this field of investigation at the present time and an excellent historical review of earlier literature may be found in Hegler (:01). The discussions center chiefly around (1) the presence or absence of a nuclear structure and its behavior in cell division, (2) the distribution of the blue-green pigment (phycocyan) and the structure of a possible chromatophore, and (3) the nature of certain conspicuous inclusions within the cell, called cyanophycin granules and slime globules. An outline in tabular form of the views of some thirty investigators on these subjects is given by Olive (:04, p. 10).

Writers from the earliest periods of cell studies on the Cyanophyceæ have recognized the presence of a central body in the interior of the cell more or less sharply differentiated from the peripheral region, which holds the coloring matter and certain inclusions. The central body contains granular material which stains and behaves in other particulars like chromatin. But as a rule this granular material is not confined within a membrane or vacuolar cavity which has proved the most serious difficulty to its acceptance as chromatin and the central body as a nucleus. Then many investigators have not been able to satisfy themselves that the central body exhibits the phenomena characteristic of nuclear division even in a simple form. Consequently much doubt has been expressed as to its morphology and possible relation to a nucleus.

The most recent and detailed investigations have, however, brought forward much evidence to the effect that the granular material in the central body is chromatin which becomes organized into chromosomes that are distributed by a form of mitotic division. In the vegetative cells, which generally divide rapidly, the chromatin is never held within a nuclear membrane but in young heterocysts and spores such inclosing membranes have been found (Olive, :04).

Olive (:04) has given especial attention to methods of sectioning and staining on the slide and presents the most detailed account of the structure and behavior of the chromatin and the simple apparatus which brings about the division of the central body. The central body is made up chiefly of dense kinoplasm with a fibrillar structure in which lie chromosomes that may be counted and whose number is found to be constant in several species. Thus there are eight chromosomes in a species of Glœocapsa and Nostoc and sixteen in certain forms of Oscillatoria, Phormidium, and Calothrix. The chromatin in some cases was observed to be organized into what seemed to be a simple type of spirem (especially clear in Glœocapsa) within the central body, and the chromosomes are formed by a concentration of material at certain points which are constant in the cells of the same plant.

Olive found evidence that the chromosomes split during the process of division of the central body and are gathered in two groups at the ends of the achromatic structure which is generally flattened at the poles and conforms in other particulars to the shape of the cells. The two sets of chromosomes are finally separated by the cell wall which develops from the periphery during cell division and cuts the achromatic structure in the middle region. That portion of the central body which remains between the two sets of daughter chromosomes is regarded by Olive as equivalent to the central spindle so well defined in stages of anaphase and telophase in mitoses of higher plants. The central body during this process of division has certainly very much the appearance of a simple type of spindle although there are not present the large fibers so characteristic of nuclear figures in higher plants. Moreover it can scarcely be held that the division is one of simple fusion when chromosomes are present in constant numbers and split into two groups with each division of the cell. Olive believes that the achromatic structure, present during cell division, is a disc-shaped, generally flat-poled spindle, densely fibrous in structure and that the fission of the chromosomes and their separation into two sets constitutes a true mitotic division of the central body, which is a nucleus.

Other authors as Scott ('88), Hegler (:01), Bütschli (:02), and Kohl (:03), also believe that the central body is a nucleus which divides mitotically but none has described the process as so closely similar to nuclear division in higher plants as in the account of Olive. Some of their results are criticized by Olive as based on preparations in which the stain was not properly differentiated or the sections were too thick. Among the recent writers Wager (:03) stands alone as holding that the nucleus divides directly (amitotically) by a process of simple fission. Both Kohl and Wager conceive the chromatin as in a network or convolute spirem which breaks up into segments which are drawn apart, thread by thread, quite a different process from the splitting of organized chromosomes. Other authors have held that the granules in the central body were chromatin although they were not willing to admit the structure as a nucleus. Thus Macallum ('99) found that the central body contained phosphorous and "masked iron" to a conspicuous degree and he, with other investigators, has shown that this structure resists the action of artificial gastric juice, solutions of pepsin, etc. These chemical reactions are considered confirmatory of the theory that the granular material is a proteid of a high order of organization such as would be expected of chromatin. However, such chemical tests are very difficult to apply and do not seem to the writer so important in establishing the nature of the central body as does the careful study of its structure and activity during cell division. The objection that the central body lacks a membrane, universally present around resting nuclei of higher plants, is not regarded as vital by Olive. In the first place such a membrane may be found around the resting nuclei in young heterocysts and spores and its absence in vegetative cells is probably explained by the rapidity of the successive cell divisions. There are some recent writers, as Massart (:02) and Zacharias (:00, :03) who are still unconvinced that the granules in the central body are chromatin and that the structure is the equivalent of a nucleus. Their papers and figures, however, clearly show that they have failed to find the detailed structures of other investigators.

Fischer ('97) has been the most conspicuous opponent of the

view that the cells of the Cyanophyceæ and also of the Schizomycetes contain nuclei, taking a position in sharp opposition to that of Bütschli ('96). Fischer's conclusions were based on his failure to find that differentiation of the protoplasm within the cell demanded by the conception of the central body and the activities of this structure during cell division as described by other authors. He presented a sharp criticism of the conclusions based on the reaction of stains in determining the nature of protoplasmic structures, criticisms largely directed against the investigations of Bütschli. He showed by some ingenious experiments upon emulsions of albumen fixed on a slide that stain reactions were a purely physical phenomenon. Thus the same combinations of stains, such as saffranin and gentian violet, may be made to give exactly opposite results in differentiating a mixture of large and small globules of albumen when used in reverse order. He attached no importance to the so called affinity of a protoplasmic structure for a particular stain and would not accept such apparent affinity as evidence of its chemical nature. The fact that the central body takes chromatic stains did not seem to him important evidence of its nuclear character and he was very positive in his belief that the cells of the Cyanophyceæ do not contain nuclei and that the central bodies should not be considered the phylogenetic forerunners of such structures.

This attitude of Fischer towards conclusions based on stain reactions was later presented in more elaborate form in his critique ('99) on methods of fixing and staining protoplasm and has had an important influence on methods of cytological investigation and interpretation. The stain reaction is now regarded as probably merely a physical phenomenon but an effective means of differentiating protoplasmic structures. The determination of their morphology rests with an understanding of their history and behavior in the activities of the cell. Although Fischer's general criticism of methods of cell research was timely and in some instances richly deserved, nevertheless his particular conclusions respecting the cell structure of the Cyanophyceæ and the Schizomycetes have not been sustained by investigators who have followed the history of the protoplasmic structures in the cells of these organisms.

We may pass now to the peripheral region of the cell which holds the blue-green coloring matter of the Cyanophyceæ. A number of investigators, as Wager (:03), Kohl (:03), Hegler (:01), and Hieronymus ('92), have held that this pigment was contained in minute granules distributed throughout the cytoplasm under the cell wall. These granules have at times been termed chromatophores or plastids and Hegler has proposed for them the name cyanoplastids. Other authors, especially Fischer ('97), Nadson ('95), Palla ('93), and Zukal ('92) have been unable to find these color-bearing granules and have believed the coloring matter to be uniformly diffused throughout the peripheral region of the cell. Fischer has made a particularly thorough study of the reactions of the pigmented region to various acids in comparison with the chromatophores of higher algæ and concludes that no plastids are present but that the color is held in a hollow cylindrical or spherical outer layer of protoplasm which may be termed a chromatophore. Olive supports Fischer, approaching the subject from a very different point of view. If minute plastids are present they should be visible in fixed and stained material and Olive is unable to find any trace of Hegler's cyanoplasts. The granules of the outer region of the protoplast seem to be colorless inclusions.

Perhaps the most confused part of the discussion on the structure of the cell of the blue-green algæ is that which deals with certain inclusions. There are apparently two sorts which are very common in the cells: (1) the cyanophycin granules (Borzi) and (2) the slime globules. The cyanophycin granules are very apt to lie along the cross walls in filamentous forms or in other peripheral regions of the cell. They are generally believed to be a form of food material and it has been suggested that they are the first visible product of photosynthetic processes, but their chemical nature is under dispute. The slime globules lie more frequently in the interior region of the cell close to the nucleus and frequently within this structure. They have been termed nucleoli by some authors and also confused with chromatin. Besides these two bodies, other minute globules have been described as oil or fat and some remarkable crystalloid structures have been figured, especially by Hieronymus ('92).

Indeed the entire subject is so confused that it does not seem desirable for us to take it up in detail at this time, especially since these inclusions are apparently all secretions or excretions and not morphological features of the cell. The most comprehensive discussions of the subject will be found in the papers of Hegler (:01), Kohl (:03), and Zacharias (:03).[1]

Schizomycetes (*Bacteria*).—The history of research upon the cell structure of the Schizomycetes has run in large part parallel with that on the Cyanophyceæ. The clearest results have come from studies upon the larger forms of the sulphur bacteria, especially certain species of Beggiatoa, and on certain forms of Spirillum. The more minute types and pathogenic forms in particular have proved very baffling because of their small size and it can scarcely be said that we fully understand their cell structure. As in the Cyanophyceæ, investigators of the bacteria fall into two groups: one holding that the Schizomycetes entirely lack a nucleus and the other that there is present a structure, often termed a central body, which is the equivalent of a nucleus.

Bütschli ('96, :02) has been the most conspicuous advocate of the latter view. He described and figured clearly a central body in the cells of Beggiatoa, Chromatium, and Spirillum with the same organization as given in his account of that body in the Cyanophyceæ. The central body contains granular material which Bütschli regards as chromatin and the structure is shown in stages of division. Bütschli has no hesitation in giving the central body the value of a nucleus. It lies within a peripheral

[1] Since the above was written a lengthy paper by Fischer, "Die Zelle der Cyanophyceen" has appeared (*Bot. Zeit.*, vol. 63, p. 51, 1905), too late to be included in these reviews. Fischer has not changed his conclusions on the chief points as discussed in his earlier papers. The chromatophore is a closed cylindrical structure; the cyanophycin granules are proteid in character; glycogen and another carbohydrate, anabænin, are conspicuous substances in the cell; the central body is not a nucleus but the seat of important metabolic processes concerned with these carbohydrates, and its contents and behavior in cell division have only a superficial resemblance to nuclear structure and mitosis; the chromatin granules of Bütschli, Olive, and others are masses of anabænin (a carbohydrate). Fischer's criticisms are fundamental and it is evident that the morphologists must clearly establish the proteid nature of the central body and its contents (especially the "so called" chromatin granules) before they can expect the acceptance of their conclusions as to its nuclear character.

region of protoplasm as in the Cyanophyceæ. There is of course no blue-green pigment (phycocyan) in the cells of bacteria and consequently no chromatophore but several sorts of inclusions may be present in the protoplasm. The nature of some of the inclusions is not clear and this subject has not been given as much attention as in the Cyanophyceæ. It is significant that this cell structure should be found so clearly in the Beggiatoa since this organism seems very close to Oscillatoria in its morphology. Some of the larger species of Beggiatoa may be expected to yield conclusions similar to those of Olive's investigation on Oscillatoria if sectioned and critically stained, especially as the cells are very large in some forms and there is probably less extraneous matter to complicate the interpretation of the preparations.

As has been stated, investigations upon the smaller species of bacteria and especially upon pathogenic forms have met with great difficulties. These led at one time to the ingenious theory of Bütschli ('90), followed by Zettnow ('97) that possibly the entire protoplast had the value of a nucleus. That is to say, an outer peripheral region of cytoplasm had either never been developed in these organisms or, if present, had become so closely associated with the chromatin that it could not be distinguished as a special region of the cell. A peripheral region of cytoplasm is represented in some of the larger forms by the cilia and by accumulations of protoplasm at the ends of the cells, especially clearly shown in Spirillum (Bütschli, '96; Zettnow, '97). Later Zettnow ('99) and Feinberg (:00) applying the staining method of Romanowski, followed by several later investigators with improved technique (Nakanishi, :01, and others), succeeded in differentiating a minute body in the cells of smaller bacteria and pathogenic forms, which is regarded now as similar to the central body of the sulphur bacteria and a true nucleus. This structure is very minute since it occupies a portion of these exceedingly small cells. Naturally it will be very difficult to obtain any detailed knowledge of its structure and behavior during cell division. But enough seems to be known to justify the belief that differentiated nuclear structures are probably present even in the smallest types of bacteria. A recent paper

of Vejdovsky (: 04) describes and figures a simple type of spindle in *Bacterium gammeri* and *Bryodrilus ehlersi* with a separation of two groups of chromatin granules during mitosis.

The chief critics of the conclusions that the cells of Schizomycetes are nucleated have been Migula ('95) and Fischer. The latter author in particular has devoted considerable attention to the group especially in his paper of 1897 which is largely a discussion of Bütschli's ('96) results on studies of the blue-green algæ and bacteria. Fischer considers the central body described by Bütschli in the sulphur bacteria as merely a vacuolate region of the cell made conspicuous by the arrangement of the sulphur grains and that the structure does not appear in cells which are free from sulphur. The granular material, considered as chromatin by others, is regarded by Fischer as reserve material. The central body described by Bütschli in the cells of Spirillum is stated to be a product of contraction. In general the same criticism which Fischer applied to the methods of staining and interpretation of structures in the Cyanophyceæ is presented for the Schizomycetes. Fischer cannot justify Bütschli's ('90) view that the smaller bacteria are chiefly composed of nuclear substance, a view which probably has few if any followers to-day and could scarcely claim to be more than a passing suggestion. In short, Fischer finds no evidence of a nuclear structure in the Schizomycetes but curiously ends by declaring that the group has no affinities with the Cyanophyceæ but that its forms are closely associated with the Flagellata.

Saccharomycetes (*Yeasts*).— The structure of the yeast cell has been perhaps the subject of as long a series of investigations as the cells of the Cyanophyceæ and Schizomycetes, and the problems in both cases have many similar features. The chief problem in the yeasts has concerned the presence or absence of an organized nucleus or its equivalent in the form of some simpler structure. The accounts range from a complete denial of its presence to descriptions of a nuclear apparatus of considerable complexity which passes through some rather involved activities during cell division. It is impossible for us to treat the subject historically. We shall only consider the accounts of the most recent investigators and try to determine the probable

bearing of these studies. An admirable review of the early literature is presented in Wager's paper of 1898.

Wager ('98) himself has made one of the most detailed studies of the yeast cell and his conclusions on the presence of a "nuclear apparatus" will be made the starting point of our discussion. The yeast cell contains a structure, termed by Wager a "nuclear body," generally situated at one side, close to the cell wall. This body resembles the nucleolus of higher plants in its homogeneous structure and reaction to stains. Besides the "nuclear body" Wager finds a vacuole always present which contains granular material and is an important part of the nuclear apparatus. This "nuclear vacuole" must be carefully distinguished from other vacuoles of the usual type which merely contain glycogen. There are besides some globular bodies in the protoplasm whose nature may be oil in some cases and proteid in others. The "nuclear body" is always in close contact with the "nuclear vacuole" but is never within it. The amount of granular material in the nuclear vacuole is variable but it sometimes contains a dense mass. This content is believed to be chromatin from the behavior to stains and insolubility in digestive fluids. Sometimes the nuclear vacuole disappears but in such cases the granular network is found in contact with the nuclear body and sometimes distributed about it in a very regular manner. The chromatic granular material appears then to be a permanent substance in the cell and always closely associated with the nuclear body, sometimes distributed about it and sometimes included within a special vacuole.

Wager concludes that the nuclear apparatus consists of (1) a nucleolus (nuclear body) and (2) a store of chromatin in a network, either enclosed in a vacuole in close contact with the nucleolus or lying freely about the nucleolus or sometimes disseminated in granules generally throughout the cytoplasm. Wager believes that the nuclear vacuole arises from the fusion of numerous small vacuoles which lie around the chromatin granules which thus come to lie within a common vesicle. This mode of origin seems reasonable from what we know of the history of the nuclear vacuole which arises around the chromosomes that gather at anaphase of mitosis to form daughter

nuclei in higher plants. The earlier investigators for the most part failed to recognize the chromatic granules and network and considered the nucleolar body (nucleolus) to be the nucleus of the cell. Janssens and Leblanc ('98), however, described a nucleus with a membrane containing caryoplasm and a nucleolus, and other authors noted the vacuole and believed that it held some relation to the nucleus.

Both the nuclear vacuole and the nuclear body (nucleolus) take part in the process of bud formation. The bud appears on the opposite side of the cell from the nuclear body and the nuclear vacuole lies between. The bud contains at first cytoplasm alone; then the nuclear vacuole begins to pass into it and the nuclear body takes a position in the vicinity, between the mother-cell and the bud. The nuclear body now divides by simple fission and one half enters the bud. The nuclear vacuole gradually constricts and is drawn apart in the canal between the two cells. The two daughter nuclear vacuoles and nuclear bodies then pass to opposite ends of the mother- and daughter-cells respectively. If the nuclear vacuole is absent the chromatin network is drawn apart so that a division is effected in a similar manner.

At the time of spore formation, the chromatin is reported by Wager to become so closely associated with the nuclear body that the two substances cannot be easily separated and behave as one. The resultant structure elongates and divides by constriction and the subsequent divisions are of the same character. Strands of deeply staining protoplasm between the daughter nuclei are of interest as suggesting the possibility of a simple type of spindle. Wager describes the formation of spore walls around the nuclei enclosing a portion of the protoplasm and thus cutting the spores out from the remaining non-nucleate cell contents. The details of this process are not known and might prove very interesting since the process, from Wager's account, would seem to be one of free cell formation without, however, the characteristics described by Harper in spore formation within the ascus. It should be more thoroughly studied for it is possible that the division will be found to involve cleavage furrows and really prove to be a type of segmentation by constriction (Section II, *Amer. Nat.*, vol. 38, p. 453, June, 1904).

Several papers have appeared on the structure of the yeast cell since Wager's account of 1898. Marpmann (:02) and Feinberg (:02) described much simpler conditions than are reported by Wager, and recognize scarcely more than a deeply staining body which they term a nucleus. Hirschbruch (:02) gives an extraordinary description, accompanied by diagrammatic figures, of a nuclear structure and a body, staining red and blue respectively, which are supposed to fuse previous to the development of a bud, but the account is so unsatisfactory as to merit little attention. Janssens (:03) reviews the work of these investigators and others in comparison with his earlier results (Janssens and Leblanc, '98). Guilliermond (:04) has published the most recent paper presenting more completely his conclusions of an earlier investigation in 1902.

Guilliermond's conclusions have some points of resemblance to those of Wager. He finds a nuclear vacuole containing a granular network believed to be chromatin and a nucleolar structure. The entire body seems to be a true nucleus, not differing in its essentials from the nuclei of other fungi. Sometimes all the material in the nucleus seems to be condensed into a central body, a sort of chromatin nucleolus (chromoblast) somewhat resembling a similar structure in Spirogyra. Guilliermond figures the nucleus as constricting during the process of budding, one part passing into the daughter cell. His figures show clearly deeply stained material outside of the nuclear membrane in a position similar to that of Wager's nucleolar body (nucleolus).

These points of agreement seem to justify at least in part Wager's account, but of course the peculiarities of both lead one to suspect that there are important features in the structure of the nucleus and in the events of nuclear division which have not been determined. It certainly seems probable that chromatin is present in definitely organized bodies (chromosomes) sometimes within a vacuole and sometimes lying around a nucleolar structure. The latter also holds an intimate relation to the chromatin, which is frequently true in higher plants. There are indications that a simple type of spindle is present at least in the nuclear divisions during spore formation. In view of

Olive's results in studies on the Cyanophyceæ it does not seem unreasonable to hope that more accurate staining of very thin sections will bring the peculiarities of these accounts into harmony with mitotic phenomena of higher forms.

The accounts of conjugation in yeasts (Barker, :01 and Guilliermond, :03) which were discussed under "Asexual Cell Unions and Nuclear Fusions" in Section IV give no additional information on the essential structure of the yeast cell.

2. Comparisons of the Structure of some Higher Types of Plant Cell with Simpler Conditions.

Some of the most fruitful and interesting fields of investigation in cell structure are likely to be in those border groups between the very simplest conditions of the lower algæ and fungi and the higher regions where the nucleus and processes of mitosis have clearly the essential features which are generally ascribed to this structure and its activities. At present the gap seems very great between the simple conditions of the Schizophyta and the groups of algæ and fungi on the next higher general level. But as a matter of fact we know almost nothing of the nuclear structure in the lowest groups of the Chlorophyceæ, *i. e.*, among the simplest of the unicellular green algæ. It is rather remarkable that this region should have been so neglected.

The Nucleus.— Comparative studies on the nucleus naturally treat chiefly of the chromosomes and nucleolus. One of the most interesting features of more recent research on the nucleus has been the steady accumulation of evidence indicating that the nucleolus holds a very important relation to the chromatin content. There are types among the lower algæ in which the whole or a greater part of the chromatin is gathered into a dense nucleolar body in the resting nucleus. Spirogyra is the best known illustration of this condition and has been studied by several investigators. Similar phenomena have been reported by myself in Corallina (Davis, '98), by Golenkin ('99) for Sphæroplea, and by Wolfe (:04) for Nemalion. Some nuclei, however, particularly in the higher plants have nucleoli whose

substance does not seem to contribute directly to the chromosomes and these have been regarded as secretions within the nucleus. Strasburger believed that such were masses of reserve material drawn upon by the kinoplasm during the process of spindle formation. The term plastin has been applied to such substance in the nucleolus and also in the linin as cannot be directly connected with chromatin. A nucleolus may consist of plastin alone, or have with this substance varying quantities of chromatin. Nucleoli consisting of chromatin alone may be expected among the lower plants from the studies on Spirogyra, Corallina, Sphæroplea, and Nemalion. Plastin and chromatin are probably closely related substances.

A recent paper of Wager (: 04) indicates that the nucleolus of some higher plants holds a far closer relation to the chromosomes than has been supposed and rather weakens Strasburger's theory of the structure as a reserve mass drawn upon during mitotic activities. This study and recent papers by Miss Merriman (: 04) and Mano (: 04) have all been upon the cells of root tips while the conceptions of Strasburger and others have been founded largely on the structure and behavior of the nucleolus in the spore mother-cell during the mitoses of sporogenesis. Wager treats of the root tip of Phaseolus, Miss Merriman of Allium, and Mano of Solanum and Phaseolus. They are important contributions to the subject of the nucleolus and should be considered in any treatment of this structure. The papers appeared too recently to be noted in our brief account of the nucleolus in Section I which is consequently incomplete. Wager's paper especially presents an excellent review of the literature on the nucleolus in the plant cell.

Wager concludes that the nucleolus is really a portion of the nuclear network and that the spirem is derived in part at least from this structure. Material from the nucleolus then passes into the chromosomes. Also, in the reconstruction of the daughter nuclei the chromosomes are massed together at a certain stage and from this mass the nucleolus emerges, taking out with it the greater part of the chromatin. Wager then considers the nucleolus as a store of chromatin which must be taken into account in theories of heredity based on the morpho-

logical independence of the chromosomes. Miss Merriman reports the origin of the nucleoli as masses among the meshes of chromatin from which they draw their substance. Mano, in contrast to Wager, holds that the nucleoli appear as globules independent of the chromatin network and later flow together into a single body. The chromosomes are also believed by Mano to be morphologically independent of the nucleolus and if the latter furnishes material to the former it is not by the emergence of strands as described by Wager. Mano then holds the nucleolus to be an accessory structure without morphological relation to the chromosomes.

The theory of the individuality of the chromosomes is of course vitally concerned with the problem of the morphology of the nucleolus but this topic we have reserved for later treatment under the caption : "The Essential Structures of the Plant Cell and their Behavior in Ontogeny." The chromatin and nucleoli within the nucleus of a higher plant lie in a vacuole whose fluid content is bounded by a plasma membrane similar to that around any vacuole in the cell. Lawson (:03) and Grégoire and Wygaerts (:03) have emphasized this structural condition in recent papers but the central idea seems to be an old one running through the writings of Strasburger from an early period.

We bring up these striking conceptions of nuclear structure in the higher plants because it seems very probable that a much clearer understanding of the problems will come through investigations upon the simpler conditions in the lower plants. There, we may hope to find evidence of the primitive forms of nucleolar and chromatic associations with perhaps some clues as to the manner of the development of the higher types of structure. Thus the yeast cell, as reported by Wager ('98) with its chromatin sometimes collected within a vacuole and sometimes distributed in the cytoplasm and a nuclear body (nucleolus) in close association with the nuclear vacuole, but not within, is of the greatest interest as presenting intermediate stages in the complexity of nuclear structure and illustrates what may be hoped from further research among the lower forms.

The Chromatophore and Plastid.— In considering the great variety of chromatophores and plastids exhibited among the

thallophytes one notices at once certain features of their distribution in various groups. The large chromatophores are characteristic of the cells of simpler and more primitive groups and the small plastids, numerous in the cells, are generally present in types which are at a fairly high evolutionary level. There are exceptions of course to this general statement but some of these are probably significant of phylogenetic relations.

The evidence all indicates that the primitive type of chromatophore was a large structure in the peripheral region of the protoplast and with an ill defined boundary or occupying the entire surface of the cell. This type of structure is at present characteristic of chromatophores of the Cyanophyceæ and is also present in numbers of the lower groups of green algæ. Thus we may find many types in the Pleurococcaceæ whose cells contain a pigment so diffused that it is impossible to establish definite limits and similar conditions often appear in the cells of some of the higher algæ as in Hydrodictyon and certain simple forms of the Ulothricaceæ.

The simple diffused types of chromatophores of the lower algæ become replaced in higher groups either by sharply differentiated structures of definite form and often showing internal organization in the form of pyrenoids or by numerous plastids. There is considerable evidence that the plastids have arisen by the successive splitting or division of large organized chromatophores. The most highly differentiated chromatophores are found in the Conjugales and the remarkable size and symmetry of these cells is emphasized by the same peculiarities of the chromatophores. They are generally so placed in the cells as to give an almost perfect balance of protoplasmic structure. This principle is especially clearly illustrated among the desmids and in such forms as Zygnema and Mougeotia while even Spirogyra illustrates the principle strikingly in the distribution of its spirally wound chromatophores.

Plastids are characteristic of the Siphonales, Charales, most of the Rhodophyceæ, the higher Phæophyceæ, and all groups generally above the thallophytes. It seems to be the type of structure best suited to cell activities since with few exceptions it is found in groups in the highest lines of plant evolution in

various directions. The only striking exceptions to this broad principle are Anthoceros, whose cells contain each a single large chromatophore, and Selaginella. Selaginella is especially interesting for, while the cells of the meristematic region and young organs contain but a single chromatophore, this structure may divide later in some types to form a chain of discoid plastids in older cells connected with one another by delicate strands of protoplasm. Thus in the life history of certain species of Selaginella we have plainly shown the change from a single chromatophore to a number of plastids. It seems probable that this history repeats in general outline the evolutionary history of the condition characterized by numerous plastids within a cell from a primitive type of cell structure with but a single chromatophore. Anthoceros and Selaginella may be regarded as forms whose cells still retain the primitive conditions with respect to the single large chromatophore. There are somewhat similar illustrations in the Rhodophyceæ as in Nemalion and Batrachospermum whose cells hold a single large chromatophore while most of the more highly organized red algæ have numerous plastids. A beautiful series of stages illustrating the evolutionary principles outlined above might be worked out in the Phæophyceæ.

What is the fundamental principle underlying the substitution of numerous plastids in a cell in place of a single chromatophore? The author believes that it must have relation to the preservation within large cells of a certain balance of the metabolic centers. The fission of a plastid is a process of constriction and studies on Anthoceros (Davis, '99, p. 94) indicate that the bounding cytoplasmic membrane exerts pressure upon the elongating structure. It seems probable that the division is due to the mechanical separation of material that is too bulky for the most effective results of photosynthesis which in the case of a single chromatophore are centered in a particular region of the cell. By the division of a chromatophore into numerous plastids the photosynthetic activities are distributed among several centers and a much better balance results within the cell. It is very interesting that the large elaborate chromatophores with their peculiar internal differentiations, the pyre-

noids and caryoids, should have been displaced by the much simpler and apparently homogeneous plastids.

A comparative study of chromatophores and plastids from the point of view of their evolutionary history is much to be desired and such research would necessitate extensive studies among the lower groups of algæ and especially in the Protococcales. Such studies would involve far more than the general morphology of the chromatophore and plastid. The structure and activities of the pyrenoid are a very important subject as shown by the investigations of Timberlake on Hydrodictyon and nothing is known of the function of the caryoid. A detailed investigation of the chromatophore or plastid throughout ontogeny is yet to be made.

The Cytoplasm.— There is no region of the plant cell whose structure is more varied and as little understood as that presented by the cytoplasm with its diverse conditions. We have throughout these papers held to the classification of Strasburger that the cytoplasm may be separated into two forms: kinoplasm and trophoplasm, which show certain structural peculiarities and are characterized by very different forms of activity. While it must be acknowledged that kinoplasm and trophoplasm are very similar in certain regions of the cell and at certain periods of the cell history, still the distinctions are in general clearly marked.

Kinoplasm is homogeneous in structure, either minutely granular or consisting of delicate fibrillæ composed of very small granules placed end to end. The homogeneous condition is characteristically shown in the three forms of plasma membranes which cytoplasm places between itself and external or internal surface contacts. The three membranes are: the outer plasma membrane, the nuclear membrane, and the vacuolar membranes. They are certainly closely related and probably identical in structure and appear to be the natural expression of protoplasm to contact with a fluid (water) medium. The fibrillar condition appears during mitosis and serves important functions in the mechanism (spindle) through which the chromosomes are distributed and in most of the higher plants determines the position of the cell wall that is generally formed with each nuclear division.

But the manifestations of kinoplasm during nuclear division and also in relation to cilia-bearing surfaces are exceedingly various and it is among these structures that our ignorance of relationships and modes of origin is deepest. These kinoplasmic structures have been described in various connections throughout this series of papers and especially in Sections I, II, and III, and need not be treated here. But the point which should be emphasized in this connection is the necessity of the close study of their simplest expressions in the lower regions of the thallophytes. The most varied forms of kinoplasm are in the thallophytes where asters, centrospheres, and centrosomes obtain and where ciliated cells, presumably with blepharoplasts, may occupy long periods of the life history. It is here that we must search for information that will bring order out of the confusion of our present accounts and insufficiency of knowledge. The most vital problems relating to kinoplasm concern the origin and the events of the simplest types of mitotic phenomena and the formation of cilia. We have a fairly clear understanding of the general features of mitosis in the groups above the thallophytes and their relation to the lower types and these will be briefly treated in the following portion of this section under the head: "Some Apparent Tendencies in the Evolution of Mitotic Phenomena." But the events of mitosis among the thallophytes are exceedingly various and difficult to understand and nothing is known of their origin or relation to the simpler conditions which must be present in the lowest regions of the Chlorophyceæ and in the Cyanophyceæ.

Trophoplasm comprises all of the cytoplasm included within the plasma membranes. While this region does not give rise to such highly differentiated cell organs as the kinoplasm, nevertheless some remarkably interesting structures are developed. Cœnocentra and Physodes are specialized structures of exceeding interest and our ignorance of the latter is truly remarkable. Nematocysts if trophoplasmic offer another attractive subject for investigation. In a sense, chromatophores and plastids may be considered trophoplasmic but their high grade of specialization and fixity as cell organs gives them a certain independence of other structures in the cell. Respecting the structure of the

groundwork of trophoplasm, whether fibrillar, granular, or presenting the structure of foam, botanical science has as yet furnished very little systematic study and this field of research is one of exceptional opportunity for the student of the plant cell.

The Cell Wall.— The cell wall may be treated from two points of view: either with respect to the strict chemistry of its organization and development or more largely for the biological and morphological features involved. The chemistry of the cell wall is an exceedingly complex subject which has developed a special literature of its own. In the substance termed cellulose we are not dealing with a single body but rather with a large group of closely related bodies. And besides the members of the cellulose group there may be present foreign substances so intimately associated with the carbohydrates as to resist very severe treatment. We cannot even touch this phase of the subject; a brief review of its complexities and problems is presented by Beer (:04) and there are further references in Section I of these "Studies."

There are, however, some biological features of the process of wall formation, the morphological and physiological aspects of the phenomena as they are related to protoplasm, which offer some exceedingly interesting problems especially among the thallophytes. It has long been a matter of dispute whether the cell wall is a secretion from the surface of a plasma membrane or is formed wholly or in part by the transformation of such a membrane.

It seems to be established now that substances of the cellulose groups are only formed in contact with plasma membranes, that is, they are not formed actually in the interior of protoplasm although they may appear to lie in such situations. Thus the material of the capillitium of the Myxomycetes which is of the same character as the chief substance in the exterior covering of the fructification, is laid down within vacuoles in the protoplasm, and is therefore in contact with the surface of vacuolar plasma membranes precisely as the outer covering lies in contact with the surface of the outer plasma membrane. The morphological relation of capillitium and outer covering to the surface of plasma membranes is therefore precisely the same.

And similarly the cross wall which takes the position of the cell plate at the end of mitosis is not developed from the transformation of a film of protoplasm but is laid down between two surfaces that separate to form a thin vacuole which later spreads to the edge of the cell and the wall is deposited between these two membranes which are almost in contact. There are a number of cases in which large strands or masses of protoplasm have been described as changing directly into cellulose but it is probable that these examples upon further study will exhibit the same relation of the cellulose substances to plasma membranes as in the typical cases of wall formation. There are many interesting examples of cellulose formation whose precise relation to the protoplasm has not yet been determined.

Respecting the exact method by which a cellulose wall is laid down by a plasma membrane there is very little real information. It is clear now that the cellulose is not a secretion from the plasma membrane comparable to a mineral shell. There is much evidence that protoplasm is actually sacrificed in the development of cellulose. There are numerous illustrations, as in the tracheids and other cells empty of protoplasm, where the final secondary thickenings are deposited as the protoplast grows smaller and eventually disappears, a large part of its substance evidently contributing to the deposits which are members of the cellulose group. But of course it cannot be supposed that the molecules of the proteids are changed directly into those of the carbohydrates. Nevertheless it does seem clear that the carbohydrates appear simultaneously with the disappearance of the proteids and occupy the position formerly held by the latter. It is probable that with the splitting up of the proteid molecule, carbohydrate material is formed which displaces the proteid substances. So in a broad sense the cellulose deposit actually does represent a transformation of a plasma membrane.

The evidence in general favors the view that the wall, lamellæ, and other deposits of cellulose only increase in amount when in actual contact with a plasma membrane. Some apparent exceptions to this principle are easily understood. Thus cell walls or portions of such may swell greatly and become much softer in consistency and perhaps even mucilaginous. There are no

reasons for regarding such transformations as an actual increase in the carbohydrate material for it is clear that the substance is a body with a greater amount of water in its organization than is present in the more usual forms of cellulose compounds. But there are some cases which are not so easily understood and perhaps the most widely known are the megaspore walls of certain species of Selaginella. These spores are remarkable for a differentiation of the spore wall in which the outer layer seems to be entirely separated from the inner by a space and yet is able to increase enormously in size and take on marked peculiarities of structure, but apparently without any relation to the protoplast. It may, however, be justly questioned whether the apparent space between the inner and outer wall is really a cavity and may not be filled with plastic material which holds the two walls in intimate organic relation to one another and to the protoplast. Miss Lyon has recently given this subject attention and announced her belief that the latter condition obtains. Her conclusions will be awaited with interest.

As regards the way in which a cell wall increases in size we are still limited to the two conceptions termed (1) growth by apposition and (2) growth by intussusception. The first method consists in the laying down of successive layers by the plasma membrane and results in a thickening of the cell wall. It is of course a comparatively simple process. Growth by intussusception is a stretching or expansion of the substance which seems to be greatly increased in quantity although the morphology of the structure remains the same. The current explanation outlined by Nägeli assumes that new molecules of carbohydrates are intercalated among the old. It seems more probable that the increase in bulk is due to some modification or rearrangement of existing molecules, involved, perhaps with an increase of material but not through the actual intercalation of new molecules of the same or original carbohydrates. The chemistry of the carbohydrates is so complex that great changes of form, bulk, or optical properties may be readily assumed which would quite change the appearance of a structure without, however, necessitating the transportation of new carbohydrate substance to it directly.

There are many forms, particularly among the lower plants, where studies on the processes of wall formation are sure to throw much light on the fundamental problems which we have discussed. And a particularly interesting study might be made of the evolutionary history of the cell wall among the thallophytes and in the modifications introduced when plants pass from aquatic habits to aërial or terrestrial conditions. Our attention has been chiefly centered on the structure of the protoplast and the morphology and behavior of its parts. We are likely soon to give more study to the carbohydrate membranes and walls and this subject is likely to be very fruitful for investigation.

3. Some Apparent Tendencies in the Evolution of Mitotic Phenomena.

Our brief descriptions in Section II (*Amer. Nat.*, vol. 38, p. 431, June, 1904) of the various kinoplasmic structures developed during mitosis in different groups of plants brings up the problem in their relationships to one another, *i. e.*, the evolutionary tendencies in the differentiation of mitotic phenomena. We have seen that the thallophytes present an especially diverse assortment of kinoplasmic structures associated with the spindle and its method of development. The spindle fibers, whether formed within the nuclear membrane (intranuclear) or arising from without (extranuclear), are associated with centrosomes or centrospheres to form asters in a number of well known types as Stypocaulon, Dictyota, Fucus, Corallina, certain diatoms, the ascus, and the basidium. Centrospheres are found in certain phases of the life history of liverworts as in the germinating spore of Pellia. A second type of kinoplasmic structure resembling in certain features the aster but with some fundamental differences has been termed the polar cap. The polar cap is an ill defined region of kinoplasm, generally larger than a centrosphere and without clear boundaries, which forms a region for the insertion of spindle fibers. Polar caps are well illustrated in the mitoses of vegetative tissues and meristematic regions, especially among the higher plants (pteridophytes and sperma-

tophytes). They sometimes approach the centrosphere very closely in their morphology.

The third and highest type of spindle formation in plants is that illustrated in the mitoses within the spore mother-cell which were given special treatment in Section III (*Amer. Nat.*, vol. 38, p. 725, October, 1904). In this remarkable cell the spindles develop from a mesh of independent fibrillæ which at prophase more or less completely surround the nucleus. The poles of the spindle arise by the grouping of cones of fibrillæ so that a single axis is finally established but without any kinoplasmic centers at the poles. This type of spindle formation which may be termed the free fibrillar type is one of the most interesting cytological peculiarities of plants. It has been found in all types whose sporophytic phase terminates its history with a spore mother-cell, although the accounts in the Hepaticæ are not in full accord.

Is it possible to connect the various types of spindle formation with one another and to establish any evolutionary tendencies in the processes involved; and have the different manifestations of kinoplasm such as centrosomes, centrospheres, polar caps, free fibrillar condition, and the mysterious structure called the blepharoplast any genetic relation to one another? The confusion is so great among the thallophytes that the author sees little hope at present of establishing clearly any relationships between the types of centrospheres and centrosomes with their systems of radiations (asters) and we must patiently wait for more information. And respecting the origin of these structures from the simpler types of mitosis we are absolutely in the dark. But the relation which polar caps and the free fibrillar type of spindle formation bear to centrospheres is less perplexing and it seems possible to define certain common features among these structures which hold them together with a degree of unity in their relations to mitosis. That phase of the subject will be considered in this treatment. The Hepaticæ as a group occupy an interesting position with respect to the character of mitotic phenomena at various periods of ontogeny, between conditions in the pteridophytes, which are obviously similar to the spermatophytes, and conditions in the thallophytes. This was brought

out by the work of Farmer whose accounts of centrosomes and centrospheres in the germinating spores of Pellia and within the spore mother-cell of various liverworts, together with his account of a "quadripolar spindle" made it evident that the group offered some very interesting cytological problems. They led the author to the study Anthoceros (Davis, '99) and Pellia (Davis, :01), investigations which have been followed by Van Hook (:00) on Marchantia and Anthoceros, Moore (:03) on Pallavicinia, Chamberlain (:03) and Grégoire and Berghs (:04) on Pellia, while Ikeno (:03) has studied the processes of spermatogenesis in Marchantia.

My studies on sporogenesis in Anthoceros and Pellia led me to conclude that the processes of spindle formation did not differ in any essentials from those in the pteridophytes and spermatophytes. There are present two successive mitoses and the spindles are formed from a surrounding mesh of fibrillæ developed from the kinoplasm associated with the nuclear membrane and without achromatic centers (centrospheres or centrosomes). They exhibit clearly the free fibrillar type of spindle formation although in somewhat simpler form than in the pteridophytes and spermatophytes. The poles of the spindles generally end bluntly in areas of granular kinoplasm but these seem to me too indefinite in form to deserve the designation of centrospheres and such granular inclusions as may be present are too variable in number and position to be termed centrosomes. There is clearly present in Pellia during the prophase of the first mitosis a four-rayed achromatic structure which is later replaced by a typical bipolar spindle. This four-rayed kinoplasmic structure is evidently the same as Farmer's "quadripolar spindle" which he described as associated with a simultaneous distribution of the chromatin in Pallavicinia to form at once four daughter nuclei. I was led to doubt this account and to suggest that the "quadripolar spindle" might prove to be simply a phenomenon of prophase associated with the peculiar four-lobed structure of the spore mother-cell in the Jungermanniales. I stated my belief that the distribution of the chromosomes during sporogenesis in all liverworts would be found to take place through two successive mitoses after the usual manner. Moore (:03)

has recently studied an American species of Pallavicinia and has failed to confirm Farmer's conclusions. He found the four-rayed figure, which Farmer terms a "quadripolar spindle," a conspicuous feature of the first mitosis here as in Pellia but there was no indication of a simultaneous distribution of quadrupled chromosomes to form four daughter nuclei as reported by Farmer. The four-rayed figure was merely preliminary to the first mitosis whose spindle at metaphase was bipolar and the first mitosis was followed shortly by a second, so that Pallavicinia offers no exception to the essential features of sporogenesis as known in all groups above the thallophytes.

Farmer (*Bot. Gaz.*, vol. 37, p. 63, 1904) has taken exception to the restriction of the term spindle by Moore and myself to the structure found at metaphase and holds that the four-rayed structure is a part of the spindle apparatus. In this discussion he appears to avoid the issue, which is not the broader or narrower application of the term spindle, a mere matter of usage, but concerns the fundamental character of the mitoses during sporogenesis whether they are two in number and successive in all forms or whether Pallavicinia presents an extraordinary exception in a distribution of the chromatin to form four daughter nuclei simultaneously in the spore mother-cell. Farmer (: 05) has recently reaffirmed his view that the poles of the four-rayed figure in Aneura and presumably in other Jungermanniales are occupied by centrospheres and that sometimes a central body (centrosomes) may be distinguished in each. This statement involves again a matter of usage in which I should differ from Farmer for my studies and those of Moore do not seem to me to justify the application of these terms to regions of kinoplasm whose form is so ill defined and history so transient within the cell.

These disputed points which were also discussed in Section III (*Amer. Nat.*, vol. 38, pp. 727–732, October, 1904) are of importance in relation to the mitotic phenomena in other periods of the life history of liverworts which will now be considered. It may be stated, however, that other investigators who have studied the processes of sporogenesis in the liverworts (Van Hook, : 00; Chamberlain, : 03; Grégoire and Berghs, : 04) sup-

port my general program of sporogenesis with the free fibrillar type of spindle formation. There seems to be little question but that centrospheres are present and conspicuous in the early mitoses within the spore of Pellia. They have been especially studied by Farmer and Reeves ('94), Davis (:01), Chamberlain (:03), and Grégoire and Berghs (:04). All of these authors have agreed that asters are clearly defined in the early mitoses within the spore and most of them have termed the region of kinoplasm in the center of the aster a centrosphere. The structures are less prominent in the third mitosis and are perhaps replaced in later periods of the gametophyte history by kinoplasmic polar caps. Polar caps are characteristic of the mitoses in the seta of Pellia (Davis, :01). However, Van Hook has described centrospheres with radiations at the poles of the spindles of the archegoniophores of Marchantia, whose centers sometimes contained centrosomes, and it is possible that the centrosphere runs through a considerable period in the life history of liverworts. There is complete agreement that the centrospheres when present arise *de novo* and independently of one another during the prophase of mitosis and that they disappear at telophase. Ikeno has, however, described centrosomes during the mitoses within the antheridium which are said to divide and pass to opposite sides of the nucleus where they become the poles of the spindles. They cannot be found after the mitosis is completed, but are described as formed *de novo* in the interior of the nucleus and thrust through the nuclear membrane into the cytoplasm previous to each mitosis. After the final division in the antheridium, the centrosome remains to function as a blepharoplast.

Thus we see that the liverworts present during their life history an almost complete range of kinoplasmic structures associated with the nuclear divisions from centrosomes and centrospheres to polar caps and that type of spindle formation characterized by free fibrillæ gathered into cones but entirely independent of definitely organized centers. There is also present the blepharoplast. I emphasized this range of kinoplasmic structure in my paper on Pellia and it seemed to me one of the most interesting features of the liverworts. In this paper

(Davis, :01, p. 171) are outlined the changes in form which kinoplasm may assume in the mitoses of the liverworts upon which is based a theory of a cycle through which kinoplasm may run in the history of a cell. On this theory, centrosphere, polar cap, and the free fibrillar condition are all secondary developments from a primal finely granular kinoplasm which is the only form of kinoplasm that is in any sense permanent in the cell. This finely granular kinoplasm is always present in characteristic form in the plasma membranes of the cell. The substance of centrospheres, polar caps, and fibrillæ arises from accumulations of granular kinoplasm during prophase and these structures return to the same undifferentiated granular kinoplasm at the end of mitosis or become lost in the general cytoplasm of the cell.

The cycle is from an undifferentiated finely granular kinoplasm through certain specialized conditions either wholly or in part fibrillar in structure back to the granular state. The centrosphere and polar cap are regions from which fibrillæ develop at least in part and to which they may remain attached as to an anchorage. The polar cap is a less clearly differentiated kinoplasmic center than the centrosphere but does not differ from it in the essentials of its organization. It seems to me that the two structures are very closely related in the liverworts and that in this group we may readily conceive the polar cap as derived from the centrosphere. The free fibrillar type of spindle formation is a step farther in the direction of such a distribution of the kinoplasm that no very positive centers for the development of the spindles may be distinguished. The four-rayed structure (quadripolar spindle) so characteristic of the spore mother-cell in the Jungermanniales represents a group of four temporary centers for the formation of fibrillæ and there is clearly a gathering of kinoplasm at these points but the regions are so vague in outline as hardly to justify the designation of centrospheres. From the fibrillar state, kinoplasm returns to the finely granular condition by the contraction of the fibers which thus contribute their substance to some common area. The area may lie around the chromosomes of the daughter nuclei where it becomes later in part at least a nuclear mem-

brane. Or the area may be a cell plate whose halves on division finally merge with outer plasma membranes of the cells. The spindle fibers which cut out the spore areas in the ascus form the basis of a plasma membrane. Thus the fate of all kinoplasmic fibrillæ seems to be a final return to the undifferentiated, finely granular condition so characteristic of plasma membranes which according to this theory is the condition from which they arose.

Thus I believe the liverworts present rather striking evidence of a relationship between the centrosphere, polar cap, and the free fibrillar condition of spindle formation and establish an evolutionary tendency from the first two types of kinoplasmic differentiation towards the latter. The free fibrillar type of spindle formation is found in a very simple form in this group, sometimes with temporary centers, as in the four-rayed figure (quadripolar spindle) of prophase, whose poles have accumulations of kinoplasm in the position of centrospheres. The polar caps are likely to prove a much simplified type of centrosphere whose kinoplasm is no longer gathered to form conspicuous spherical centers.. With respect to the problem of the homologies and nature of the blepharoplast, the liverworts furnish as yet no material assistance and this structure stands at present as one of the most interesting puzzles of plant cytology. As stated in the beginning, the variety of centrosomes and centrospheres with and without radiations in various types of the thallophytes seems to me too confusing to promise an understanding of their relationships at present.

Grégoire and Berghs (:04) have interpreted the structure of the mitotic figure in the germinating spore of Pellia in a very different manner from the accounts of Farmer, Chamberlain, and myself. They consider the asters to arise through a rearrangement of the cytoplasmic network around the nucleus. They affirm that there are no true centrospheres nor any accumulations of granular kinoplasm to constitute the centers of origin for the spindle fibers or the radiations around the poles of the spindle. The centers of the asters ("vésicules polaires") are said to have a vesicular structure and neither they nor the nucleus contributes to the building up of the spindle which is

developed entirely out of the cytoplasmic network. The authors are unable to distinguish a kinoplasm distinct from the general network of the cell. These are vital points of difference which are fundamental to the understanding of mitotic phenomena and rest of course on matters of fact. The chief points at issue concern the structure and development of the asters and the nature of the material at their centers. My own studies and those of Farmer and Chamberlain have convinced me that there is an accumulation of substance (kinoplasm) in the centers of the asters and polar caps to such an amount that it must be regarded as a definite structure in the cell and its morphology and relations to the spindle have certainly justified us in considering it as similar to the centrosphere of the thallophytes.

4. The Essential Structures in the Plant Cell and their Behavior in Ontogeny.

The cell is composed of a series of osmotic membranes between which are included a number of protoplasmic structures whose morphology and minute organization is various. They are: the outer plasma, the vacuolar, and the nuclear membranes. Each of these sustains a relation to some fluid which bathes its surface. The fluid nature of the nuclear sap and cell sap is obvious but the outer plasma membrane is also against a moist surface since the cell walls of tissues are normally saturated with water. The structure of the plasma membranes is apparently the same. They consist of the homogeneous finely granular protoplasm that is designated kinoplasm. The protoplasmic structures included within the plasma membranes may be grouped as cytoplasmic and nuclear. The greater part of the cytoplasm, including that which is termed trophoplasm, has an organization peculiar to itself and very different from that of the plasma membranes. This structure has been described as alveolar or of the nature of foam and sometimes fibrillar and with various large granular inclusions. The cytoplasm also contains the characteristic organs termed plastids. The conspicuous structures of the nucleus are: the chromatic elements

appearing as chromosomes during mitosis and the nucleoli. These structures are so easily recognized and play such important parts in the events of nuclear division that they command attention at once as the essential elements in the nucleus. The nucleus may also contain other material such as linin which, however, does not seem to have a fixed form or behavior in the cell. Finally there are certain kinoplasmic structures, as centrosomes, centrospheres, and blepharoplasts, whose behavior throughout cell history has been much discussed. We shall now consider the most important of these structures, those which seem essential to the cell in ontogeny.

The outer plasma membrane naturally retains its morphological entity throughout all cell divisions with such slight changes as when new parts are intercalated into its area through the vacuoles that are utilized in the segmentation of protoplasm. Vacuolar membranes are constantly shifting and cannot be followed during cell division excepting in such cells as have one large central vacuole (the tonoplast of De Vries). Such a central vacuole is much more characteristic of old cells and tissues than of young or embryonic regions. There is certainly no reason to suppose that it has organic existence through any very extended period of the life history. The nuclear membrane becomes lost during the prophase of mitosis and there is much evidence that its kinoplasm contributes in some cases to the formation of spindle fibers. Thus the nuclear membrane disappears as a structure in the cell during mitosis and new vacuoles are formed around the assemblages of daughter chromosomes during telophase, leading of course to the formation of fresh nuclear membranes at their surface of contact with the surrounding cytoplasm.

There is perhaps no region of the cell protoplast that presents such different appearances through long periods of the cell history as the trophoplasm. This is largely due to the varying character of the inclusions which are not in themselves protoplasmic but which give a mixed structure to the trophoplasmic regions of the cell. The inclusions may be carbohydrate or proteid bodies held within spaces in the trophoplasmic groundwork or they may be globules of oil or fatty substances. These

inclusions occupy small spaces in the trophoplasm which are essentially vacuoles. There is also a class of granular inclusions of a proteid nature which probably represent material in very close organic relation to the substance of protoplasm. Trophoplasm does not then have so clearly defined a type of structure as do the other regions of the protoplast but it is hardly probable that its essential nature changes very materially throughout the life history. The organization of trophoplasm is itself a matter of dispute but the prevailing views favor an alveolar or foam structure with a fibrous character at times somewhat resembling the texture of sponge.

Ever since the classical investigations of Schimper upon the plastid it has generally been held that these structures are permanent organs of the cell, reproducing by fission, and carried along from one cell generation to the next with as much permanence as the nucleus. Schimper discovered plastids in the oöspheres of certain spermatophytes and in a variety of embryonic tissues and concluded that the structures passed from parents to offspring as leucoplasts when no trace of color could be found in the reproductive cells or embryonic tissues. There has been, however, no systematic study of the plastid throughout the life history of higher plants and in most of the green thallophytes there are reproductive phases, such as resting spores, where we have no knowledge of the structure or distribution of the chromatophores in the cell. It is very important that the plastid be investigated with the same degree of attention which has been given to the nucleus, and that it be followed through all periods of the life history in forms where the color becomes greatly modified or is absent in the reproductive cells and embryonic (meristematic) regions of the plant. Anyone who has studied the embryonic tissues of plants will realize the difficulties of the investigation which will probably involve the development of methods of technique, especially of staining, somewhat different from those generally employed in cell studies.

We may now consider the elements in the nucleus and their behavior during ontogeny. This is one of the most interesting subjects in cell studies, for the importance of the chromosomes

and chromosome history in relation to problems of development, heredity, hybridization, and variation is clearly understood, and these subjects have already been treated in Section V, "Cell Activities at Critical Periods of Ontogeny in Plants." Also some recent papers on the nucleolus of which Wager's (:04) is the most comprehensive, have brought this structure into very close relation with the chromatin content of the nucleus, and the nucleolus must now be considered in any treatment of the chromosomes. The problems hinge on what is termed the individuality of the chromosome, which is the question whether or not the chromosome is a structural entity maintaining its independence completely through each and all of the cell divisions in a life history. There is also involved the view that the chromosomes have come down from a line of ancestral structures, reproducing by fission in every mitosis throughout the history of the race.

There are two extremes in the views on this exceedingly interesting conception and also an intermediate position. The one extreme has recently been set forth by Boveri (:04) in a very clear statement. This view regards the chromosomes as structural entities, possibly elementary organisms, which maintain an organic individuality and independent existence in the cell. They are further regarded as in their typical form when present as rods or short filaments during mitosis. Their behavior in the resting nucleus is one of great metabolic activity which affects their morphology for the time being.

Those who are inclined to doubt the individuality of the chromosomes and to hold off from a full acceptance of the theory, base their attitude on the extreme difficulty or perhaps impossibility of following the chromosomes as entities through the resting nucleus from one mitosis to another. These difficulties are well known to those who have studied chromosomes even in nuclei which are most favorable for the investigation of their morphology. The chromosomes which enter the daughter nuclei from a mitosis generally lose their form and the chromatin becomes so distributed on a linin network or in a nucleolar structure that the outlines of the original structures become quite lost. Mottier (:03) in his recent studies on the spore

mother-cell of certain angiosperms has emphasized these points and Grégoire and Wygaerts (:03) have also shown the difficulties of following the chromosomes in the resting nuclei of the root tip and spore mother-cell of Trillium, stating that the structures become resolved into an alveolar network.

On the other hand Rosenberg (:04) claims that the chromosomes may be clearly recognized in the resting nuclei of some forms and cites *Capsella bursa-pastoris* as a particularly good illustration. In this plant the chromosomes are described as small granular bodies scattered throughout the nucleus in fixed number at various stages of ontogeny. Thus there are 16 in cells of the gametophyte and 32 in those of the sporophyte while 48 of these bodies were counted in the nuclei of the endosperm as would be expected if these nuclei are descendants of a triple fusion in the embryo-sac. Similar conditions are reported in other forms and there is considerable evidence giving weight to the view that chromosomes may be actually followed through all periods of the nuclear history in some favorable types.

Apart from the actual demonstration of the chromosomes in the resting nuclei and their recognition as structural entities through successive cell divisions there is much general evidence in support of the theory of the individuality of the chromosomes. This evidence lies in the nuclear fusions of fertilization and the mitoses of processes of segmentation that follow where the chromosomes are known to remain separate and have been distinguished as maternal and paternal. Also, as we have seen from the discussions of reduction phenomena at sporogenesis and the behavior of the chromosomes in hybridization, there are good reasons for believing that maternal and paternal chromosomes remain separate all through the sporophyte generation and are distributed to the offspring during sporogenesis. The importance of these events in the minds of all investigators has rested very largely on the behavior of the chromosomes and has led to the very general assumption that they must stand for units of organization and may be counted as constant factors in the problems of heredity. It is not necessary to adopt Boveri's extreme views to hold still the theory of the individuality of the chromosomes. Nor is it necessary to assume that the structures

have a distinct organization which holds throughout the life history. The form of the chromosomes certainly does change with different periods of the cell's history especially within the resting nucleus and yet the centers of chromosome activity may always be present to organize the chromatin into a new set of elements for the next mitosis. It is perhaps difficult to believe that the chromatin granules (chromomeres) find their way back to the same chromosome with the prophase of each mitosis but the existence of chromosome centers may be readily conceived within the resting nucleus which would hold the number of chromosomes true to the cell's history.

With respect to the nucleolus there is abundant evidence that the structure is not a permanent organ of the cell. When containing chromatin, the nucleolus is found in its characteristic globular state only during the resting condition of the nucleus. Its chromatic substance passes into the chromosomes at prophase of mitosis and the nucleolus generally disappears before metaphase. Or if any substance is left after the chromosomes are formed the remaining structure either gradually dissolves or is thrust forth bodily into the cytoplasm surrounding the mitotic figure where it disappears sooner or later. The nucleolus in higher types of mitosis never divides to pass on with the chromosomes to the daughter nuclei, but such a history is reported in the yeast cell. If the nucleolus has any function in heredity, as has been claimed (Dixon, '99), such function must relate to the chromosomes which contribute to its substance or derive material from it. Besides the nucleoli which are composed wholly or largely of chromatin, there are also those which seem to have little if any relation to the chromosomes. Such are well known in the spore mother-cells of higher plants and no investigator has been able to connect these with the formation of chromosomes as Wager (: 04) has been able to do in the root tip. It was upon nucleoli of this class that Strasburger founded his theory that the structure was a mass of reserve material utilized by the kinoplasm during mitosis in the process of spindle formation. Such nucleoli generally fade away during the prophase of mitosis and either entirely disappear or the remaining substance is thrust out into the cytoplasm where it may some-

times be recognized as deeply staining globules (the so called extranuclear nucleoli).

There is left for our consideration that group of kinoplasmic structures termed centrosomes, centrospheres, and blepharoplasts which, when accompanied by radiations, are called asters. Some authors regard these structures as homologous and believe them to be present in one form or another as permanent organs of the cell in certain types (see discussion of Ikeno, :04). Against this view stand the well established facts of an increasing list of forms, both animals and plants, in which these structures unquestionably arise *de novo* at certain periods in the cell's history. To the author this evidence seems insurmountable and he cannot believe that the aster is in itself a permanent organ of the cell. We shall not take up the subjects of relationships here for such discussions have proved of little profit except in special cases where the various types of structure are found in closely related forms or in the same life history, and these have scarcely been studied at all. We know so little about the relationships in the thallophytes, where relationships must be sought if present at all, that a satisfactory treatment of the subject is hardly possible at present. One point seems to have escaped attention in the writings of those who have discussed the centrosome problem. The active elements of the asters are not the central structures (centrosomes, centrospheres, or blepharoplasts) but the fibrillæ which play such important parts as spindle fibers or cilia. This fibrillar condition of kinoplasm has a fixed place in the cycle of cell division appearing with each mitosis and at the time of cilia formation, but the fibrillæ are not permanent structures of the cell. There is some evidence that the centrosomes, centrospheres, and blepharoplasts are merely regions for the development and attachment of these fibrillæ and as such may stand as the morphological expression of fibrillæ-forming dynamic centers rather than as organs which actually induce the development of fibrillæ.

5. The Balance of Nuclear and Cytoplasmic Activities in the Plant Cell.

Two regions of the cell are sharply distinguished from one another with respect to both morphology and physiology. They are the nucleus and the cytoplasm. The nucleus soon dies if isolated from cytoplasm and the latter, lacking a nucleus, cannot be kept alive indefinitely unless it be in organic connection with a nucleated mass of protoplasm. The necessary connection may be only through delicate strands, as was established by Townsend ('97), and also seems to be illustrated in the instances of intercellular protoplasm which Michniewicz (:04) reports are connected by delicate fibrillæ (plasmodesmen) with neighboring cells. Some very interesting adjustments of the nucleus and cytoplasm to one another have been reported in a series of investigations of Gerassimow beginning in 1890. His most recent papers of the past year (Gerassimow, :04a, :04b) present a general summary of his studies and constitute a very important contribution to the subject. They will furnish much of the material for this discussion.

Gerassimow has found that the cells of Spirogyra and other members of the Conjugales offer admirable material for the study of the relations between the nucleus and cytoplasm, and throw important light on the functions, physiological activities, and interdependence of both structures. By subjecting filaments of Spirogyra during cell division to a temperature of 0° C. or treating them for a short time to the anæsthetic influence of ether, chloroform, or chloral hydrate it is possible to arrest the processes of mitosis at different stages with the result that the protoplasm may become variously distributed in the daughter cells. (1) A daughter cell may be formed lacking a nucleus but containing a portion of the divided chromatophore in a peripheral layer of cytoplasm. (2) A single cell may contain the two daughter nuclei either separated from one another or more or less intimately associated and perhaps wholly fused depending upon how far the processes of mitosis have progressed before the cells have been subjected to the shock of the

experiment. (3) Binucleate cells may continue their growth with subsequent mitoses which when treated as before may give daughter cells with three nuclei and one nucleus respectively or with two each or indeed a cell containing four nuclei. Furthermore these nuclei may fuse with one another to give structures with a greatly increased chromatin content. (4) In place of the non-nucleated cells there may be formed chambers containing cytoplasm and chromatophores, but without nuclei, which remain in open communication with the nucleated companion protoplast because the cell wall is not formed entirely across the mother-cell.

Gerassimow has made some extended observations on these various types of cells, and presents his results in many elaborate tables and diagrams. We can only give an outline of his conclusions. (1) Cells which come to contain unusually large nuclei through the suppression of mitosis or by the reuniting of partially divided daughter nuclei increase proportionally in size and their further cell division is postponed. The nuclei of such cells have of course the peculiarity of an increased amount of chromatin content. The large nuclei may later fragment into two or more structures which separate and generally come to lie at a distance from one another in the cytoplasm. The fragments finally lose their powers of reproduction and exhibit marked evidence of degeneration. (2) Cells which lack nuclei may form starch in the usual manner in the presence of light and exhibit for a short time a weaker general growth than normal nucleated cells. The power to develop a gelatinous sheath also becomes markedly weakened. Finally there result a decrease in the volume of the cell, a fading of the chromatophore, and conditions which lead to eventual death. (3) Chambers which lack nuclei but are in protoplasmic union with nucleated cells may be contrasted sharply with the non-nucleated cells. They exhibit a much stronger growth for a longer time and with a greater power to form starch, although not so marked as in the nucleated cells, and the chromatophores retain their color. There is also a conspicuous development of the gelatinous sheath.

Haberlandt, Klebs, Pfeffer, Strasburger, and others have dis-

cussed the relations of the nucleus to the surrounding protoplasm with respect to both dynamics and morphology. Klebs ('88) indeed anticipated some of the work of Gerassimow, studying the non-nucleated cells of Zygnema and Spirogyra and noting the ability of their chromatophores to form starch in considerable quantities but the inability of the protoplast to add to the cell wall. Klebs was able to keep these non-nucleated cells alive in a sugar solution for from four to six weeks. But for the most part the discussions of the balance of nuclear and cytoplasmic activities in the plant cell have been very general in character.

Some principles have been, however, widely held for several years and may be summarized. The necessity of the nucleus to the life of the cytoplasm has been clearly understood but the studies of Klebs and Gerassimow indicate that the nucleus is not directly concerned with the process of photosynthesis which apparently may go on in non-nucleated cells as long as the cytoplasm retains a certain degree of vitality. A non-nucleated cell may enlarge slightly but it is not probable that the amount of protoplasm is increased. An especially interesting feature of non-nucleated cells is the inability of the outer plasma membrane to form cellulose walls or outer membranes. But the very interesting studies of Townsend ('97) have shown that this power may be retained provided the non-nucleated mass of protoplasm is connected by delicate cytoplasmic fibrils with a nucleated mass. It thus seems clear that the membrane-forming possibilities of the outer plasma membrane are absolutely dependent upon dynamic relations with the nucleus. While the chromatophore may carry on the processes of photosynthesis independently of the nucleus, nevertheless the general health of the cell requires the activities of the latter so that the nucleus becomes necessary to any extended photosynthetic work.

It has frequently been stated that the size of the nucleus is directly proportionate to the amount of cytoplasm in the cell. There are many favorable illustrations of this statement, as the extraordinarily large eggs of the gymnosperms, especially the cycads, whose nuclei are by far the largest in the plant kingdom. And in general an increase in the amount of cytoplasm is accom-

panied either by a marked enlargement of the nucleus with a corresponding increase in the chromatin content or by mitoses which distribute to the cytoplasm a greater number of nuclei whose sum total of material is very much greater than before. Conversely a sudden increase in nuclear material through nuclear fusions either sexual or asexual is followed almost immediately by general cell growth and increase in the amount of cytoplasm. However, such fixed growth relations between nucleus and cytoplasm can hardly be an established physiological law for certain highly specialized sperms have an insignificant amount of cytoplasm proportionately to the chromatin that is contained within the gamete nucleus. It is evident that the interrelations of the nucleus and the cytoplasm are so intimate that the growth activities of the one must benefit the other, but that this principle can be formulated in definite mathematical ratios seems improbable.

The dependence of the nuclei upon favorable situations in the cytoplasm is clearly shown in cells when a partial or general nuclear degeneration takes place. Thus during the processes of oögenesis in the Peronosporales, Saprolegniales, and in Vaucheria there is present a period when the most of the numerous nuclei within the oögonia begin to break down and finally become disorganized. The causes of the nuclear degeneration are not entirely clear but apparently the organ is unable to supply all of the nuclei in their respective situations in the cytoplasm with the conditions necessary for their life. There is consequently a sort of struggle for existence among these numerous nuclei and only those that are favorably placed in the cell are able to survive. In all forms the surviving nuclei occupy a situation in the center of the masses of protoplasm which are to become the eggs and those that break down are at or near the periphery of the cell. In several genera (*e.g.*, Albugo, Peronospora, Pythium, Sclerospora, Saprolegnia, and Achlya) the surviving nuclei seem to owe their good fortune to a very close association with the cytoplasmic structure termed the cœnocentrum. The cœnocentrum is a clearly differentiated region of the cytoplasm and is probably the morphological expression of a dynamic center in the eggs of these fungi. Stevens' ('99, :01)

studies on Albugo showed that the cœnocentra exert a chemotactic influence upon the nuclei in their vicinity, drawing them towards the mass of granular material in this favored region of the cell, and it is clear that they are greatly benefited in this situation since they increase in size while the nuclei at the periphery break done. This subject is discussed in detail in my paper on Saprolegnia (Davis, :03, pp. 240–243) a form which also illustrates exceptionally well the same principles of a survival of certain nuclei among many which degenerate, because of their favorable position in the central region of the eggs in close proximity to cœnocentra. There are then undoubtedly regions of the cell more favorable for the nutrition of nuclei than others and the positions of these may be marked by morphological characters as illustrated in the cœnocentra. That similar dynamic centers may also be present when there is little morphological evidence of their existence is indicated in the processes of oögenesis in Vaucheria (Davis, :04) which exhibits the same principles of extensive nuclear degeneration as are found in the Peronosporales and Saprolegniales and the survival of a single nucleus in the oögonium, apparently because it comes to lie in a mass of granular cytoplasm near the center of the oögonium.

LITERATURE CITED IN SECTION VI, "THE PLANT CELL."

BARKER.
:01. A Conjugating Yeast. *Phil. Trans. Roy. Soc. London*, vol. 194, p. 467.

BEER.
:04. The Present Position of Cell-wall Research. *New Phytologist*, vol. 3, p. 159.

BOVERI.
:04. Ergebnisse über die Konstitution der chromatischen Substanz des Zellkerns. Jena, 1904.

BÜTSCHLI.
'90. Ueber den Bau der Bakterien und verwandter Organismen. Leipzig, 1890.

BUTSCHLI.
'96. Weitere Ausführungen über den Bau der Cyanophyceen und Bakterien. Leipzig, 1896.

BÜTSCHLI.
:02. Bemerkungen über Cyanophyceen und Bakteriaceen. *Arch. f. Protistenkunde*, vol. 1, p. 41.

CHAMBERLAIN.
:03. Mitoses in Pellia. *Bot. Gaz.*, vol. 36, p. 29.

DAVIS.
'98. Kerntheilung in der Tetrasporenmutterzelle bei *Corallina officinalis* L., var. *mediterranea*. *Ber. d. deut. bot. Gesellsch.*, vol. 16, p. 266.

DAVIS.
'99. The Spore Mother-cell of Anthoceros. *Bot. Gaz.*, vol. 28, p. 89.

DAVIS.
:01. Nuclear Studies on Pellia. *Annals of Bot.*, vol. 15, p. 147.

DAVIS.
:03. Oögenesis in Saprolegnia. *Bot. Gaz.*, vol. 35, pp. 233, 320.

DAVIS.
:04. Oögenesis in Vaucheria. *Bot. Gaz.*, vol. 28, p. 81.

DIXON.
'99. The Possible Function of the Nucleus in Heredity. *Annals of Bot.*, vol. 8, p. 269.

FARMER AND MOORE.
:05. On the Maiotic Phase (Reduction Division) in Animals and Plants. *Quart. Jour. Micr. Sci.*, vol. 48, p. 489.

FARMER AND REEVES.
'94. On the Occurrence of Centrospheres in *Pellia epiphylla* Nees. *Annals of Bot.*, vol. 8, p. 219.

FEINBERG.
:**00**. Ueber den Bau der Bakterien. *Centralb. f. Bak.*, pt. 1, vol. 27, p. 417.

FEINBERG.
:**02**. Ueber den Bau der Hefezellen und über ihre Unterscheidung von einzelligen thierischen Organismen. *Ber. d. deut. bot. Gesellsch.*, vol. 24, p. 567.

FISCHER.
'**97**. Untersuchungen über den Bau der Cyanophyceen und Bakterien. Jena, 1897.

FISCHER.
'**99**. Fixirung, Färbung, und Bau des Protoplasmas. Jena, 1899.

GERASSIMOW.
:**04a**. Zur Physiologie der Zelle. *Bull. Soc. Imp. Nat. Moscou*, no. 1.

GERASSIMOW.
:**04b**. Ueber die Grösse des Zellkerns. *Beih. z. Bot. Centralb.*, vol. 18, p. 45.

GOLENKIN.
'**99**. Ueber die Befruchtung bei *Sphæroplea annulina* und über die Structur der Zellkerne bei einigen grünen Algen. *Bull. Soc. Imp. Nat. Moscou*, p. 343.

GRÉGOIRE AND BERGHS.
:**04**. La figure achromatique dans le *Pellia epiphylla*. *La Cellule*, vol. 21, p. 193.

GRÉGOIRE AND WYGAERTS.
:**03**. La reconstitution du noyau et la formation des chromosomes dans les cinèses somatiques. I. Racines de *Trillium grandiflorum* et telophase homœotypique dans *Trillium cernuum*. *La Cellule*, vol. 21, p. 7.

GUILLIERMOND.
:**03**. Recherches cytologiques sur les levures. *Rev. Gén. Bot.*, vol. 15, pp. 49, 104, 166.

GUILLIERMOND.
:**04**. Sur le noyau de la levure. *Ann. Mycol.*, vol. 2, p. 184.

HEGLER.
:**01**. Untersuchungen über die Organisation der Phycochromaceenzelle. *Jahrb. f. wissensch. Bot.*, vol. 36, p. 229.

HIERONYMUS.
'**92**. Beiträge zur Morphologie und Biologie der Algen. *Cohn's Beitr. z. Biol. d. Pflan.*, vol. 5, p. 461.

HIRSHBRUCH.
:**02**. Die Fortpflanzung der Hefezelle. *Centralb. f. Bak.*, pt. 2, vol. 9, pp. 465, 513, 737.

IKENO.
:**03**. Beiträge zur Kenntniss der pflanzlichen Spermatogenese: die

Spermatogenese von *Marchantia polymorpha*. *Beih. z. Bot. Centralb.*, vol. 15, p. 65.

IKENO.

:04. Blepharoplasten im Pflanzenreich. *Biol. Centralb.*, vol. 24, p. 211.

JANSSENS.

:03. À propos du noyau de la levure. *La Cellule*, vol. 20, p. 337.

JANSSENS AND LEBLANC.

'98. Recherches cytologiques sur la cellule de levure. *La Cellule*, vol. 14, p. 203.

KOHL.

:03. Ueber die Organisation und Physiologie der Cyanophyceenzelle und die mitotische Teilung ihres Kernes. Jena, 1903.

KLEBS.

'88. Beiträge zur Physiologie der Pflanzenzelle. *Unters. a. d. bot. Inst. z. Tüb.*, vol. 2, p. 489.

LAWSON.

:03. On the Relationship of the Nuclear Membrane to the Protoplast. *Bot. Gaz.*, vol. 35, p. 305.

MACALLUM.

'99. On the Cytology of Non-nucleated Organisms. *Trans. Can. Inst.*, vol. 6, p. 39.

MANO.

:04. Nucléole et chromosomes dans le méristème radiculaire de *Solanum tuberosum* et *Phaseolus vulgaris*. *La Cellule*, vol. 22, p. 57.

MARPMANN.

:02. Ueber Hefen und über den Zellkern bei Saccharomyceten und Bakterien. *Centralb. f. Bak.*, pt. 2, vol. 9, p. 357.

MASSART.

:02. Sur le protoplasme des Schizophytes. *Recueil d. l'Inst. Bot. Bruxelles*, vol. 5, p. 251.

MERRIMAN.

:04. Vegetative Cell Division in Allium. *Bot. Gaz.*, vol. 37, p. 178.

MICHNIEWICZ.

:04. Ueber Plasmodesmen in den Kotyledonen von Lupinus-arten und ihre Beziehung zum interzellularen Plasma. *Oester. bot. Zeitsch.*, vol. 54, p. 165.

MIGULA.

'95. Ueber den Zellinhalt von *Bacillus oxalticus* Zopf. *Arb. a. d. bak. Inst. d. tech. Hochsch. z. Karlsruhe*, vol. 1, p. 139.

MOORE.

:03. The Mitoses in the Spore Mother-cell of Pallavicinia. *Bot. Gaz.*, vol. 36, p. 384.

MOTTIER.

:03. The Behavior of the Chromosomes in the Spore Mother-cells of Higher Plants and the Homology of the Pollen and Embryo-sac Mother-cell. *Bot. Gaz.*, vol. 35, p. 250.

NADSON.

'95. Ueber den Bau des Cyanophyceen-protoplastes. *Scripta Botan. Horti Petropoli*, vol. 4.

NAKANISHI.

:01. Ueber den Bau der Bakterien. *Centralb. f. Bak.*, pt. 1, vol. 30, pp. 97, 145, 193, 225.

OLIVE.

:04. Mitotic Division of the Nuclei of the Cyanophyceæ. *Beih. z. Bot. Centralb.*, vol. 18, p. 9.

PALLA.

'93. Beitrag zur Kenntniss des Baues des Cyanophyceen-protoplasts. *Jahrb. f. wissensch. Bot.*, vol. 25, p. 511.

ROSENBERG.

:04. Ueber die Individualität der Chromosomen in Pflanzenreich. *Flora*, vol. 93, p. 251.

SCOTT.

'88. On the Nuclei in Oscillaria and Tolypothrix. *Jour. Linn. Soc., Bot.*, vol. 24, p. 188.

STEVENS.

'99. The Compound Oösphere of *Albugo bliti*. *Bot. Gaz.*, vol. 28, p. 149.

STEVENS.

:01. Gametogenesis and Fertilization in Albugo. *Bot. Gaz.*, vol. 32, p. 77.

TOWNSEND.

'97. Der Einfluss des Zellkerns auf die Bildung der Zellhaut. *Jahrb. f. wissensch. Bot.*, vol. 30, p. 484.

VAN HOOK.

:00. Notes on the Division of the Cell and Nucleus in Liverworts. *Bot. Gaz.*, vol. 30, p. 394.

VEJDOVSKY.

:04. Ueber den Kern der Bakterien und seine Teilung. *Centralb. f. Bak.*, pt. 2, vol. 11, p. 481.

WAGER.

'98. The Nucleus of the Yeast Plant. *Annals of Bot.*, vol. 12, p. 499.

WAGER.

:03. The Cell Structure of the Cyanophyceæ. *Proc. Roy. Soc. London*, vol. 72, p. 401.

WAGER.

:04. The Nucleus and Nuclear Division in the Root Apex of Phaseolus. *Annals of Bot.*, vol. 18, p. 29.

WOLFE.

:04. Cytological Studies on Nemalion. *Annals of Bot.*, vol. 18, p. 607.

ZACHARIAS.

:00. Ueber die Cyanophyceen. *Abhand. a. d. Gebiete d. Naturwissensch*, vol. 16.

ZACHARIAS.

:03. Ueber die Cyanophyceen. *Jahrb. d. hamburg. wissensch. Anstalten*, vol. 21, p. 49.

ZETTNOW.

'97 Ueber den Bau der grossen Spirillen. *Zeitsch. f. Hyg.*, vol. 24, p. 72.

ZETTNOW.

'99. Romanowski's Färbung bei Bakterien. *Zeitsch. f. Hyg.*, vol. 30, pl. 1.

ZUKAL.

'92. Ueber den Zellinhalt der Schizophyten. *Ber. d. deut. bot. Gesellsch.* vol. 10, p. 51.

DIADASIA PATTON; A GENUS OF BEES.

T. D. A. COCKERELL.

THE genus Diadasia was first described by Patton in the *Bulletin of the United States Geological Survey* (vol. 5, p. 475). The type is the *Melissodes enavata* of Cresson, which, as Patton showed, is nearer to Anthophora than to Melissodes. The genus occurs in our southwestern States, and is, undoubtedly, of neotropical derivation. Ashmead has recently placed it as a synonym of the South American Ancyloscelis Latreille, but it appears to me to be sufficiently distinct.

Our species of Diadasia have not hitherto been tabulated, and as I have now seen all the species but one, I offer tables for their identification. The species of Cresson are in the collection at the Philadelphia Academy; I have been permitted to borrow cotypes from that institution, through Mr. Viereck, and this has enabled me to clear up several doubtful points. *Entechnia toluca* (*Melissodes toluca* Cresson) and *Dasiapis ochracea* Ckll., are included in the table, as the first has for some years stood in our lists as a Diadasia, while the latter is often mistaken for a species of that genus.

FEMALES.

Hair of head and thorax above short and dense, orange fulvous; abdomen with four clean cut bands of fulvous tomentum on a black ground; outer side of basal joint of hind tarsi with very long, strongly plumose, dark chocolate-colored hairs; inner side of this joint with shining dark ferruginous hair; tegulæ red; flagellum all dark; front rough with very close punctures . . . . *sumichrasti* (Cresson).

Hair of thorax not thus colored; or if fulvous, abdomen not thus banded 1.

1. Scopa on outside of hind legs dark gray or blackish (in *afflicta* paler on basal part of tibiæ.) . . . . 2.

Scopa on outside of hind legs white, or not gray or blackish . 4.

2. Very small; less than 8 mm. long; abdomen with narrow bands of tomentum on apical margins of segments; mesothorax and scutellum

minutely, extremely densely punctate all over, therefore rough and not shining . . . . *Entechnia toluca* (Cresson).
Larger; at least over 8 mm. long; mesothorax well punctured but shining . . . . 3.

3. Large and stout; about 12 mm. long, or more *D. bituberculata* (Cresson).
Smaller; about 10 mm. long, or less . . . . *afflicta* (Cresson).

4. Very large species, about 15 mm. long . *megamorpha* Cockerell.
Large stout species, about 13 mm. long; hair of thorax above ochraceous or fulvous, with the disc bare . . . . 5.
Smaller species, less than 12 mm. long . . . . 7.

5. Hind spur of hind tibia straight or practically so; clypeus more closely punctured, the large punctures stronger . . *enavata* (Cresson).
Hind spur of hind tibia strongly bent at end; clypeus less closely punctured, the large punctures weaker . . . . 6.

6. Legs dark red; abdominal segments 3 and 4 with a narrow apical fringe, the rest thinly hairy . . . . *australis* (Cresson).
Legs black; abdominal segments 3 and 4 with lateral areas where the surface is raised and shining black, the hair on it being very sparse and dark . . . . . . *australis opuntiæ* (Cockerell).

7. Anterior edge of abdominal bands curved, the basal part of the segments dark; comparatively large and broad form: hind spur of hind legs curved at end . . . . *australis rinconis* (Cockerell).
Anterior edge of abdominal bands not curved, the pubescence, except at margin, uniformly distributed; smaller forms . . . . . 8.

8. Hair on inner side of basal joint of hind tarsi light ferruginous; abdomen entirely covered with yellowish tomentum *Dasiapis ochracea* Ckll.
Hair on inner side of basal joint of hind tarsi fuscous or black . 9.

9. Face broad, eyes scarcely converging below; eyes narrow, especially above; mesothorax shining, impunctate in middle, at sides with large scattered punctures: abdomen broad, with narrow ochreous hair-bands on hind margins of segments 2 to 4 . . *laticauda* Cockerell.
Eyes broader and shorter, distinctly converging below; mesothorax duller, the sides with very numerous feeble minute punctures *diminuta* (Cresson).
Larger than the two last (11 mm. long) and at once separated from them by having much fuscous or black hair on the abdomen; there are ochreous marginal hair-bands . . . . . . *friesei* Cockerell.

MALES.

Hair of face black . . . . *nigrifrons* (Cresson).
Hair of face not black . . . . 1.

1. Apex of abdomen truncate; tongue very long; maxillary palpi not fringed with hair: size very small . . *Entechnia toluca* (Cresson).

Apex of abdomen bidentate . . . . 2.
2. Abdomen above with much black hair on discs of segments beyond the second . . . . 3.
Abdomen above without black hair . . . . 6.
3. Large; at least 13 mm. long; apical teeth of abdomen large and divergent . . . . *bituberculata* (Cresson).
Smaller; about 10 mm. long; apical teeth of abdomen small and close together . . . . 4.
4. Hind tibiæ thickened, but shape not remarkable; basal joint of hind tarsi dark ferruginous, long, slender, and curved, its apex not produced, the hair on its inner side orange; maxillary palpi not fringed with hair, except a little tuft at the end of second joint; tegulæ light rufous *sumichrasti* (Cresson).
Hind tibiæ greatly swollen, narrowing to a very slender base, shaped something like a wine-bottle; basal joint of hind tarsi dark, not so long, with black or dark fuscous hair on inner side . . . . 5.
5. Tegulæ dark but decided red; second submarginal cell much narrowed above; hair of mesothorax white . . . . . *afflicta* (Cresson).
Tegulæ piceous: second submarginal cell scarcely narrowed above: hair of mesothorax and scutellum gray . . *afflicta perafflicta* Cockerell.
6. Basal joint of hind tarsus ending in a long process: species covered with gray hair; maxillary palpi with no fringe of long hairs, but second joint ciliate . . . . 7.
Basal joint of hind tarsus not ending in a long process . . 8.
7. Larger forms . . . . *australis* (Cresson).
Smaller, down to about 10 mm. long . *australis rinconis* (Cockerell).
8. Very large, about 16 mm. long . . . *megamorpha* Cockerell.
Rather large, length over 10 mm., the pubescence more or less ochraceous on thorax, sometimes quite fulvous; facial quadrangle longer than broad . . . . 9.
Small, length less than 10 mm. . . . . 10.
9. Hair of thorax more or less fulvous . . . *enavata* (Cresson).
Hair of thorax paler . . . . . *enavata* var. *densa* (Cresson).
10. Abdomen above shining and sparsely hairy, not banded: face broad, orbits little converging below (distinctly less than in *diminuta*) *nitidifrons* Cockerell.
Abdomen hairy, the hind margins of the segments banded *diminuta* (Cresson).
Abdomen covered with appressed white tomentum *sphæralcearum* Cockerell.

D. albovestita Provancher, I have not seen. It was described from the female; length just over 8 mm., flagellum reddish beneath, tegulæ brownish, margins of abdominal segments pale yellow and covered with dense whitish pubescence; apex red-

dish brown. It must be similar to *D. sphæralcearum*, but the antennæ are differently colored.

The following species are not considered valid : —

D. tricincta Provancher, from California, is said by Fowler to be a synonym of *enavata*. This cannot be, from the description; but it is not apparent that it differs from *afflicta*. *D. nerea* Fowler, from California, is *nigrifrons* Cresson ; *D. cinerea* Fowler, from California, is *bituberculata* Cresson. Fowler can hardly be blamed for describing these as new, as when he published his paper Cresson's species were supposed to belong to Melissodes. *D. ursina* (Cresson) is *enavata*. *D. apacha* (Cresson) is *diminuta*. The types of *apacha* have been in some liquid, presumably alcohol, and this accounts for part of their characters. I formerly separated the specimens of the Middle Sonoran zone as *apacha*, leaving those of the Upper Sonoran as *diminuta* ; but the comparison of specimens from various localities appears to show that the characters relied upon are too variable to serve for specific distinction.

Two forms are new : —

Diadasia afflicta (Cr.) subsp. **perafflicta** n. subsp.

♂. — Tegulæ piceous ; second submarginal cell scarcely narrowed above ; hair of mesothorax and scutellum gray.

♀. — This sex does not materially differ from true *afflicta*.

Hab.— Clark Co., Kansas, 1962 ft., May (F. H. Snow, 1191) ; Hamilton Co., Kansas, 3350 ft. (F. H. Snow, 460) ; Wallace Co., Kansas, 3000 ft. (F. H. Snow, 852). Three females, from the same three localities, are numbered 851, 1197, and 445.

Diadasia sphæralcearum n. sp.

♂. — Length 7½ mm. ; like *D. diminuta* Cr., but with shorter, perfectly white pubescence, and a narrower, more parallel-sided abdomen ; the pubescence of the abdomen, instead of being loose and suberect as in male *diminuta*, is appressed (except on first segment) and covers the surface ; aside from the pubescence, the hind margins of the segments are themselves white ; the apex is bidentate, the teeth being like those of *diminuta*, but rather larger ; hind legs constructed as in *diminuta* ; shining hairless triangle of metathorax much smaller than in *diminuta* ; posterior part of mesothorax almost nude ; tegulæ subhyaline, ferruginous, dark at base ; antennæ entirely black.

Hab.— Between Las Cruces and Mesilla Park, New Mexico, at flowers of *Sphæralcea fendleri lobata* (Wooton), middle of August (Cockerell). It was accompanied by *Macroteropsis latior* (Ckll.).

The distribution of the species in States, etc., so far as known, is as follows: —

MEXICO.— *D. diminuta* Cr.; *sumichrasti* Cr.; *enavata* Cr. (Lower California).

CALIFORNIA.— *D. albovestita* Prov.; *afflicta* Cr. (*tricincta* Prov.); *nigrifrons* Cr.; *bituberculata* Cr.; *nitidifrons* Ckll.; *laticauda* Ckll.; *friesei* Ckll.; *enavata* Cr.; *diminuta* Cr. (Palm Spring, *Davidson*); *australis rinconis* Ckll.; *australis opuntiæ* Ckll.

NEVADA. — *D. bituberculata* Cr.

ARIZONA. — *D. diminuta* Cr. (Bill Williams' Fork, *Snow*; Grand Cañon, *Hopkins*); *australis rinconis* Ckll. (Bill Williams' Fork and Oak Creek Cañon, *Snow*); *enavata* Cr. (Oak Creek Cañon, *Snow*).

NEW MEXICO.— *D. diminuta* Cr.; *sphæralcearum* Ckll.; *australis* Cr.; *australis rinconis* Ckll.; *enavata* Cr.; *megamorpha* Ckll.

TEXAS.— *D. australis rinconis* Ckll. (part of Cresson's original *australis*, as shown by a ♀ cotype); *enavata* Cr.; *enavata* v. *densa* Cr. (a color variation merely); *afflicta* Cr.

KANSAS. — *D. australis* Cr. (Wallace Co., and Morton Co., *Snow*); *enavata* Cr. (Wallace Co., *Snow*); *diminuta* Cr. (Hamilton Co., *Snow*); *afflicta perafflicta* Ckll.

COLORADO.— *D. enavata* Cr. (Lamar, *Snow*, Palisade, *Gillette*, Julesburg, *Ball*, Trinidad, *Titus*); *enavata* v. *densa* Cr. (Rocky Ford, in beet field, *P. K. Blinn*); *diminuta* Cr. (Fort Collins, Trinidad, *Colo. Agric. Coll.*); *australis* Cr.

D. sumichrasti Cr., is peculiar for the densely punctured mesothorax, but the blade of maxilla is broad at base and narrow apically, as in true Diadasia. The maxillary palpi are long, 6-jointed. The sexes do not look much alike, but close comparison confirms their identity.

D. australis and its subspecies may be found visiting the flowers of Opuntia. The small species, *diminuta* and its allies, are addicted to the Malvaceæ. *D. megamorpha* (♀) was recorded from the flowers of *Sphæralcea angustifolia*, but the plant was really *S. fendleri lobata*, which had not then been differentiated.

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NOTES AND LITERATURE.

GENERAL BIOLOGY.

Driesch's Naturbegriffe und Naturteile.[1] — This introduction to the author's philosophy of nature in a sense completes his systematic empirical and theoretical treatment of biology, for the present volume is, as he remarks, on the one hand the conclusion of his theoretical biological work and on the other the presentation of the results of investigations which transcend biology and even natural science itself.

In his earlier books : *Die Lokalisation morphogenetischer Vorgänge*, *Analytische Theorie der organischen Entwicklung*, *Die organischen Regulationen*, *Die "Seele" als elementarer Naturfaktor*, Driesch has discussed with insight the chief facts and principles of morphogenesis, even to the development of mind, in their relations and their theoretical bearings. He now attempts a philosophy of nature, but he has not used the title *Naturphilosophie* because he feared that the word philosophy might prevent the reading of the book by those for whom it was written ! Certainly he has ground for his suspicion that most biologists have little interest in the concepts of reality, constant, energy, measure, substance, entelechy which are analyzed in the book.

The morphology of certain concepts which are of fundamental importance in biology as well as in other natural sciences is a brief characterization of *Naturbegriffe und Naturteile.* Those who care to know what a philosophically inclined biologist thinks concerning the structure and functions of the basal concepts of his science will be interested in Driesch's work.

R. M. Y.

De Vries' Species and Varieties.[2] — The widespread interest which has been aroused by the discoveries of Professor de Vries makes the publication of this book an important and welcome event.

[1] Driesch, Hans. *Naturbegriffe und Naturteile. Analytische Untersuchungen zur reinen und empirischen Naturwissenschaft.* Leipzig, Englemann, 1904. 8vo, viii + 239 pp.

[2] de Vries, Hugo. *Species and Varieties, their Origin by Mutation*, edited by D. T. MacDougal. Open Court Pub. Co., Chicago, 1905. 8vo, xviii + 847 pp.

It is a matter of congratulation that we should now have, in English, a discussion of the mutation theory and the line of thought which led the author to put it forward, as well as an account of the experiments on Lamarck's Evening Primrose which has figured so largely in the habilitation of the theory. Not indeed that this volume is to be regarded as a translation of his *Mutations-theorie*, for without the great amount of detail found in that work it treats the subject in a broader way, aiming to bring out the mutation concept with sufficient specific illustration to support the principles enunciated. After the introductory chapter, which is of a historical nature, the discussion of what are termed elementary species affords the topic of several of the succeeding ones. Here we find a highly illuminating treatment, which, in connection with what is said later about varieties, serves to give a clarified conception of the import of the Linnean group or collective species. That the latter are, indeed, an abstract idea, an average as it were of a number of types grouped together, is brought sharply to the attention. The modern taxonomist who is in sympathy with this idea must at once see a new significance to the segregations which are constantly and often of necessity being made from the older forms which have been considered species. Elementary species are contrasted with varieties, in that they differ in more than one respect and possess qualities which are distinctly new, while in varieties the whole character difference may usually be expressed by a single term and which, as the evidence goes to show, do not possess any really new qualities. Most varieties arise in a negative way, by the loss of some quality, and much more rarely do they appear to be positive, possessing some feature new to themselves, which, however, is to be regarded as the reappearance of a character seen in allied forms. Moreover, these characters are, whether of a positive or of a negative nature, physiologic units and appear and disappear singly. From this the development of the author's line of thought leads him to the consideration of atavism and the associated subject of hybridism. In discussing true atavism all cases which might be confused with it that arise from hybridism, or from varieties which annually produce sports, are to be excluded. Atavistic tendencies in this strict sense are found to be very rare, and while reversionary forms may often be widespread in the sense of geographical distribution, it is found that this is due to bud propagation. For what the author calls false atavism he introduces a new term, — vicinism,— to carry the idea of chance spatial contiguity, which results in spontaneous and often undetected crosses. Under this head then will come many of the instances of so called atavism.

Continuing the subject of hybridism we find again a difference between elementary species and varieties in the way in which they behave when crossed. In crossing varieties all the characters are paired, though some may be latent, and the progeny follow the Mendelian law of splitting. Such crosses may be termed bisexual to contrast them with the unisexual crosses of elementary species. The latter species differing in one or more unit characters, which are not paired as in the first case, the result is a hybrid offspring which is constant.

Having brought out the differences of elementary species and varieties along the lines indicated, the author next inquires into the question of the origin of new forms and here again shows that the behavior of the two are unlike and that "sports" originating from varieties do not introduce anything really new. To treat this last-named topic the author has been constrained to coin a new term to designate varieties which produce "sports" in each generation and these he has called "eversporting varieties." The wide range of variability seen in such forms is due to the presence of mutually excluding characters, by reason of which the forms swing from one extreme to the other. In most cases, however, latency of the more or less absent character not being complete, there are intergrading forms found. Thus such sports are not in reality new forms. The appetite of the reader having been whetted by this as it were introductory matter, the discussion of the origin of new forms in the production of elementary species, that is mutation, is attacked with the greater zest. Here indeed is the climax of the book, for which the reader has been carefully prepared by what has gone before.

The subject is introduced by an account of the peloric toadflax and the origin of double flowers, but of course the major interest lies in the description of Professor de Vries' minutely careful pedigree cultures of *Œnothera lamarckiana*, Lamarck's Evening Primrose. It is not necessary here to recount the manner in which the author came to experiment on this plant, or the manner in which the experiments were carried on. In this country we are already familiar with much of this from work done here, which looks to corroboration and extension of Professor de Vries' all-important observations. It is sufficient to say that from this plant, under closely guarded conditions of culture, several markedly distinct forms or mutants were seen to arise and that these mutants have through successive generations bred true to their newly originated characters. Several principles or laws regarding mutation are deduced as follows. New

elementary species appear suddenly, without intermediate steps. New forms spring laterally from the main stem. New elementary species attain their full constancy at once. Some new strains are evidently elementary species, while others are to be considered as varieties. The same new species are produced in a large number of individuals. The mutations take place in nearly all directions.

The great difference between this and the Darwinian theory of the origin of species is that here we have new forms which are to be recognized as specifically distinct, arising in perfectly constant form, by sudden leaps, or more properly mutations, rather than by continuous slow variations. This and the fact that many individuals, whole species indeed, are mutating simultaneously, must profoundly modify the Darwinian concept. It is superfluous here to enter further into this discussion or to point out how in other ways our ideas must be rearranged to be consonant with these new facts. That the question is completely solved no one, probably the author least of all, would be prepared to admit, but that much light has been thrown on the matter can hardly be questioned. It has been said somewhere that while Professor de Vries has given us a Mutation Theory he has not given us a Theory of Mutation. That may indeed be true, but let us at least be thankful that here we have this question of the origin of species at last within the field of experimentation. Perhaps it will be possible for us to determine later what are the predisposing conditions or influences which make for mutation, whether or not there is any definite periodicity to the phenomenon. Not least important, too, is the bringing of the whole matter within the scope of physiological inquiry, and the insistence that morphological tests unconfirmed by physiological ones are only provisional. There is bound, of course, to be considerable misconception as to what really are and what are not mutations, and the intuitive plant-breeder will no doubt be tempted to lay too great confidence on the scientific value of his own experiments, yet in this way too the book, if understandingly read, will prove of the greatest value. It cannot be too often stated that the confidence one has in the results of Professor de Vries is that his were pedigree cultures guarded from contamination with the greatest care and with the complete ancestry of his plants minutely recorded from the time he undertook the work. There can, indeed, be no excuse for any scientific investigator proceeding along these lines of research in a loose or careless way after a perusal of this volume, yet it ought to, and no doubt will, stimulate many with the desire to, themselves, add something to the sum of

knowledge in these matters. The book, while necessarily somewhat technical at times, is by no means beyond the comprehension of the general reader, who knows even a little about plants.

H. M. R.

ZOÖLOGY.

Sedgwick's Text-book of Zoölogy.[1]— The second volume of Sedgwick's *Text-book of Zoölogy* is devoted to amphioxus and the vertebrates. The volume, which contains over 700 pages, may be described as a revised expansion of the vertebrate portion of Claus and Sedgwick. The expansion has been in part due to the addition of materials on fossil vertebrates which were very inadequately dealt with in the older text-book. The chapter on the Cephalochorda deals almost exclusively with *Amphioxus lanceolatus*, the structure and development of which is most admirably portrayed. Here, however, the description ends, for almost nothing of value is given concerning the natural history, distribution, or taxonomy of this important and interesting group of animals. In fact we are told that the phylum contains only a single genus, Amphioxus, a statement so conservative as to be misleading. The remaining chapters treat of the vertebrates proper and contain as a rule well balanced descriptions of the larger and smaller groups of this phylum reminding one of the treatment accorded them in Claus's classic text-book except that Sedgwick gives us an adequate account of the fossil representatives. In fact the striking feature of this new text is the complete absorption of paleontology into the body of zoölogy, a logical and natural consequence of the growth of these two sciences. In another respect, however, the new volume is strikingly out of touch with recent work; it is almost without reference to animal physiology. Although the recent results of comparative physiology are by no means as ripe for incorporation into a general zoölogical text as those of paleontology, they are certainly far too important to be omitted from such a work as Sedgwick's and they are assuredly as truly a

[1] Sedgwick, A. *A Student's Text-book of Zoölogy. Vol. II.* London, Swan, Sonnenschein and Co., 1905. 8vo, xvi + 705 pp., 333 figs.

part of zoölogy as the systematic and morphological matters that fill the pages of this otherwise excellent work. From a mechanical standpoint the book is well put together. A convenient arrangement of small and large type helps to give light and shade. An excellent index has the added convenience of indicating by the use of exponents whether a name is found in the upper or lower half of the page. Typographical errors are relatively few though Rabl-Rückhard is misspelled on page 193 and its hyphen is omitted on page 321. The illustrations are mostly familiar if not actually threadbare and for some strange reason almost all from the older Claus and Sedgwick are much less satisfactorily printed than in the earlier work. Notwithstanding such shortcomings, the volume as a whole has very much for genuine commendation, though its size promises to put the work when completed on the shelves of the teacher rather than in the hands of the pupil.

G. H. P.

Aldrich's Catalogue of North American Diptera.[1] — Catalogue-making is often a thankless task, but skillfully and conscientiously done, the results are of the utmost importance in all systematic work in biology. American entomology has been especially fortunate in its cataloguers of the two-winged insects. The last is Professor J. M. Aldrich, who has just produced a voluminous work of 680 pages, containing full lists and bibliographies of all known American species of Diptera north of South America. The work has been a stupendous one, involving most of the author's available time for the past eight years. It is, however, far more than a mere bibliographical catalogue of genera and species, since it contains many critical notes on the distribution and validity of the forms catalogued. One is surprised at the amount of work that has been accomplished in the order since the appearance of Baron Osten-Sacken's *Catalogue* in 1878. The number of known species has been nearly doubled, reaching now more than eight thousand, while the proportion of increase in the genera has been even greater, there being 1230 recognized as valid in Professor Aldrich's catalogue.

Entomologists can only be grateful for this labor of love on the author's part, for it will mark the beginning of a new epoch in the study of these insects. The writer has examined the catalogue very

[1]Aldrich, J. M. *A Catalogue of North American Diptera (or Two-winged Flies)*. Smithsonian Misc. Coll., vol. 46, 680 pp., 1905.

carefully, and is surprised at the remarkably small number of errors it contains, whether of omission or of commission. Not all will agree with the author in some of his views as expressed in his arrangements and distribution, though they seem for the most part well founded. But that matters little; the information is all there, and one does not have to follow the author if he has good reasons for not doing so.

S. W. W.

Barron's Old Whaling Days.[1]— This interesting narrative may be classed with Bullen's *Cruise of the Cachalot* as a whaling epic, written by one who started as a cabin boy and eventually became master. Bullen gave us an account of the capture of sperm whales in temperate and tropical seas; Captain Barron takes us to the arctic regions in pursuit of the Greenland right whales that follow close along the edge of the ever-changing ice pack.

Sailing first in 1849, Barron made seventeen voyages to the arctic waters, chiefly west of Greenland, in pursuit of seals and whales and gives a graphic account of the many dangers encountered in the sudden shiftings of the ice, the frequent gales and storms, and the bitter cold. About 1851, ships' crews commenced the practice of wintering in the Cumberland Sound region that they might pursue the whales with the first return of the sun after the long arctic night. The introduction of steam whalers in the late 50's did away with many of the hardships that sailing vessels imposed upon their crews. For many years, Hull, England, was the chief clearing port for the arctic whalers, but by 1869 the trade was abandoned there.

Although the author does not pretend to any scientific knowledge, he tells a number of interesting facts in regard to the habits of whales and other animals. It is stated that one right whale, on being struck, sounded at once and in 3½ minutes ran out 3600 feet of line indicating a speed of about 1000 feet a minute, which must be unusual for this species. The whale was then hauled up dead, having struck the sea bottom with such force as to break its neck. Barron also makes the interesting observation that thousands of young harp seals are sometimes killed in gales by the floe ice breaking and driving over them.

The main value of this book is in preserving a record of the perils and hardships suffered by the hardy whalers of a past genera-

[1] Barron, William. *Old Whaling Days.* William Andrews & Co., Hull; A. Brown & Sons, London, [1905]. 12mo, x + 211 pp. 3/6.

tion, their methods of work, their losses or successes, in a calling now almost past. "When the trade was at its height, there were occasionally fair fortunes made, and the crews at times were well paid. The life was frequently one of great privation, and at times of deep denial and not a little danger. There was, however, much of fascination in the pursuit of seals, whales, and other creatures of the far north, and one cannot help a feeling of regret that these days have passed away never to return."

G. M. A.

Notes.— In a paper by Miss M. J. Klem, entitled "A Revision of the Palæozoic Palæëchinoidea, with a Synopsis of All Known Species" (*Trans. St. Louis Acad. Sci.*, vol. 14, no. 1, May 5, 1904) there are a number of conclusions drawn to which attention should be called. These are mainly apparent refutations of the principles of development given by Dr. R. T. Jackson and Dr. T. A. Jaggar in their paper on "Studies of *Melonites multiporus*" and by Dr. Jackson in his paper "Studies of Palæëchinoidea" (*Bull. Geol. Soc. Amer.*, vol. 7). These apparent refutations seem to arise from a misconception of the principles of development as given in those papers. On page 2 of Miss Klem's paper the statement of the above authors that "the interambulacral area of the adult of Melonites when perfect, consists of two plates at the ventral termination" is claimed to be incorrect and she maintains that it always terminates in three plates when the specimen is perfect, citing figures 6, 8, 12, and 13 in proof. In these sixteen drawings in which the line marking the ventral border of the perfect specimen is shown but four times (in 6*b*, 6*d*, 12*c*, 13*c*) the completion of the adambulacral plates laterally to show the impingement of the ambulacral plates is lacking, a feature which would give much more definiteness to the whole series of figures. In these sixteen drawings all of which are claimed to show the invariable termination in three plates, four areas show termination ventrally in two plates (figs. 6*a*, 6*b*, 6*c*, 8*c*). This substantiates the point in question, that when perfect the area terminates in two plates as shown by Jackson and Jaggar. The other figures represent cases in which there are three or more plates ventrally which according to Jackson and Jaggar are wanting in the plates found at the ventral part of a complete specimen. On page 3 is a statement of doubt concerning the power of resorption to remove plates ventrally. Certainly a study of modern sea urchins in various stages of development would make this power of resorption perfectly clear. At the end of the page is this statement: "Furthermore, if resorp-

tion took place (which I doubt very much) by what law of nature could the plates twist themselves from the position indicated in fig. 11, pl. 3, to that shown in fig. 10, pl. 3?" A more careful reading of their explanation of the figures would show that the plates would not by any law of nature necessarily have to twist themselves in any way, as it is stated that figure 11 is adapted from one specimen, while figure 10 is drawn from an entirely different specimen which is described as aberrant.

In regard to the idea of the introduction of columns there is an entire misunderstanding of the statements of Jackson and Jaggar. They call the two columns which terminate at the ventral border, columns 1 and 2, then the next added column is spoken of as the third column, etc. Miss Klem does not make this grouping but makes one of her own, in which the early columns are ignored and the first column in her scheme is the first one added above the border shown in her figures. Therefore the first column of her scheme may correspond to the third, sixth, or any column of the other authors except what they really call the first. With such a failure to use equivalent terms it is obvious that other results are obtained especially in a group where the structure is largely one of numerical sequence. As a result of this difference in terminology, the following statement is made: "While this rule ('that .... newly added columns normally alternate to left and right as introduced, even numbered columns typically appearing on the right of odd ones') may apply to some isolated and imperfect specimens, the contrary becomes quite evident by examining a large and complete collection of perfect fossils." Twenty-three figures are referred to in order to show that the rule does not hold in usual cases. However, by using the basis of numbering given by the original authors at least seventeen out of these twenty-three figures given by her show decidedly the correctness of their rule.

A statement which needs correction is given on page 5: "Another feature, which will not stand a critical test, is the supposition of the above mentioned authors, that new columns are always introduced by a pentagonal plate with the apex pointing ventrally or toward the oral area." Exceptions are given to the rule but the fact is overlooked that the original authors show that there are exceptions, as in figure 10 where a column is introduced by a tetragonal plate, in figure 14 where one is introduced by a hexagonal plate, and in figure 16, where one is introduced by a heptagonal plate, the same variations that Miss Klem simply reiterates. The statement is made that "the initial plate of a column when pentagonal often has the

apex pointing dorsally," but there are no examples of its frequence given and in looking through the figures carefully but two cases in over a hundred show the apical angle in a position which may be considered as pointing dorsally in relation to the axis of the newly added column.

On the whole Miss Klem's paper instead of in any way disproving the views originally worked out by Jackson and Jaggar seems, in so far as it goes, to be a confirmation of them when they are reduced to equivalent terms.

The bibliography includes works that have only a bare mention of the Echini, as Zittel's *Geschichte der Geologie und Palæontologie*, while certain others are left out, the most prominent noted being Alexander Agassiz's "Revision of the Echini."

In the systematic treatment there are a number of statements which are open to criticism. On page 1 is the statement that "all the Palæozoic Echini belong to the *Class Cidaridæ*" (italics are mine). On page 10 the class is given as Echinoidea. Also on the same page is given a list of the prevailing characters on which the classification is based. In these the number of columns in the interambulacrum is left out but is nevertheless used in all the descriptions. The number of columns in the ambulacral areas and the number of pores are considered as two of the most important characters. This latter portion is due possibly to the surprising statement made that Palæechinus has four pores in each ambulacral plate. As given in the generic description Palæechinus has but two columns of ambulacral plates, but under *P. lacazei* Julien (page 34), primary and secondary plates are spoken of and one pair of pores is given with a question. Such a condition is in line with the accepted idea that all the Palæozoic Echini have a single pair of pores to each ambulacral plate.

Frequently the generic description does not agree with the characters given under the various species. For example, Lepidesthes is stated to have ten columns of plates in each ambulacral area. Five species are given, the first with 18 to 20, the second with 10 or 12, the third with 8 or 9, the fourth with 10, the fifth with 7 or 8. A summary would give 7 to 20 instead of 10. In Lepidechinus the number of interambulacral plates is given as 9 to 11. But two species are given, the first with 8, the second with 7 to 9 columns of plates in this area. Many other instances might be pointed out but these suffice to show that the statements given in this work should be carefully confirmed before being accepted.

J. A. CUSHMAN.

The mechanism by which geckos and other lizards cling to smooth overhanging surfaces has been investigated by Schmidt (*Jena. Zeitschr.*, vol. 39, pp. 551–580), who finds that the scales on the under sides of the toes of these animals carry clusters of fine hair-like bodies which, however, end in small flat faces and not in points. The under surfaces of the toes are provided with blood spaces that act as erectile organs and the whole mechanism gives no support to the idea that these animals adhere to overhanging surfaces by suction. Schmidt believes that the act of holding on to the surface is dependent upon the hair-like bodies and he is inclined to ascribe it to some electrical phenomenon produced by them.

The comparative anatomy of the Fallopian tubes in mammals has been fully worked out by U. Gerhardt (*Jena. Zeitschr.*, vol. 39, pp. 649–712).

The mutual relations of the kidneys and gonads in Haliotis have been studied by Totzauer (*Jena. Zeitschr.*, vol. 39, pp. 527–550). The two kidneys are not in communication with each other, but open separately into the mantle cavity. The rudimentary left kidney communicates with the pericardium and opens into the mantle cavity on the left side of the rectum directly. The right kidney has a well developed duct leading to the mantle cavity and also an opening into the pericardium. The gonads are discharged through their own ducts into the right kidney from which their products escape into the mantle chamber through the duct of the right kidney.

Boveri (*Jena. Zeitschr.*, vol. 39, pp. 445–524) in a series of experiments on sea-urchin eggs, has shown that abnormal numbers of chromosomes in eggs or in blastomeres are inherited unchanged by the descendant cells. Cells with abnormally large numbers of chromosomes are abnormally large and have abnormally large nuclei and the reverse. The number of cells in a growing sea-urchin larva is inversely proportional to the chromatin content thus showing a relation between the amount of chromatin and the amount of protoplasm. This relation, which is in the form of a regulation, is established through the number of cell divisions which the cytoplasm of the egg may undergo.

E. P. Felt's Report on the mosquitoes or Culicidæ of New York State (*New York State Museum, Bull. 79*, 168 pp., 57 pls.) "represents about three years' work and gives a comprehensive account of the mosquitoes occurring in New York State, with special reference

to methods of control. Some 55 species are treated, the larvæ or wrigglers of 43 are described, and accounts of their habits and life history are given. There are tables for the separation of adults and larvæ, and the value of the work is greatly enhanced by over 100 original line-drawings and 57 excellent process plates reproduced from the author's photomicrographs. The keys and illustrations should enable physicians, and in fact almost any person having a fair microscope at his disposal, to identify most of the common forms in either the adult or the larval stage. This bulletin should also appeal to teachers interested in nature study, since no group of insects lends itself more readily to class room conditions."

In a sumptuously illustrated article on the Rocky Mountain Goat, Mr. Madison Grant (*Ninth Ann. Rept. N. Y. Zoöl. Soc.*, pp. 1–36) gives an account of the characters, relationships, distribution, and habits of this peculiar group of animals. A number of photographs of living and mounted specimens illustrate the paper.

A list of the mammals of North Carolina, exclusive of the Cetacea, by C. S. Brimley (*Journ. Elisha Mitchell Sci. Soc.*, 1905) records 66 species at present known from the State. Short notes on the distribution and analytical keys for determination of the species, make it of general value to others than specialists.

ANTHROPOLOGY.

La sociologie génétique[1] — genetic sociology — occupies itself, according to the definition of the author (p. 3) with "the origin of human society and all the phenomena by which it is influenced; the term being equivalent with social embryogeny."

The writer endeavors in one small volume to give an outline of the sources and development of the essential constituents of human organization, and he is not entirely successful. He has produced a work of generalities and philosophy, on facts that are not always ample enough, or fully reliable.

The material utilized consists of (1) studies of animal societies and animal life; (2) studies of savage peoples; (3) results of

[1] Cosentini, François. *La sociologie génétique; Essai sur la pensée et la vie sociale préhistoriques.* Introduction de Maxime Kovalewsky. Bibliothéque de Philosophie Contemporaine, Paris, Alcan, 1905. 8vo, xviii + 205 pp.

palethnology and paleontology; (4) historical data concerning the progress, during long periods, of a single society; (5) ancient written laws and customs; (6) myths, popular traditions, archeologic monuments; (7) psychologic induction; and (8) survivals of culture of primitive age. In nearly all these lines the author apparently labors under the serious disadvantage of relying upon documentary evidence alone, lacking a thorough, personal, practical acquaintance with the subject, which is essential, even in the presence of good documents, to true reasoning and conclusions.

The seventeen chapters of the book treat, respectively, of the object, rôle and sources of genetic sociology; animal societies; modern savages; human races and polygenism; palethnologic data; primitive man; primitive family; primitive society; primitive propriety (possessions); primitive ideas; mythologic conceptions; language and writing; religion; morals; laws; politic organization and social classes; and art, industry and commerce. The author is at his best in the divisions on animism ("primitive ideas") and religion; the exposition of these subjects is concise and clear, and the ground is better covered than elsewhere.

The writer adheres to the polygenic theory of human evolution, and the matriarchal theory of the primitive family; he opposes the idea of society being derived from the family. The humble commencements of human society must be sought with man's immediate precursors. The actual societies of savages offer much analogy with that of primitive (early) man. Individual possessions followed propriety in common, and, beginning with a few personal effects, developed particularly with the domestication of animals. The cosmic ideas of the primitive man were those of animism. Language was preceded by mimicry and its beginnings were imitations of animal sounds; the first words consisted of imitative sounds and of gestures; the first stage of language was monosyllabism. Religion is based upon animism, which constitutes the minimum of religiosity. Morals are developed independently of religion. Laws are but moral rules, admitted and sanctioned by groups of humanity. In politic organization the clan preceded the tribe, which latter was formed by an enlargement of one or a coalition of several clans. The first class in society was the military, which later on constituted the aristocracy; the next class was the sacerdotal, the third the plebeian, etc. The various grades of the civil society, manifested at the present in space, are living documents of successive transformations accomplished in time.

In several places in his book M. Cosentini adduces, as a testimony, the status of the "peau-rouges" or Indians. The term "redskins" should once for all be abandoned. The skin of the Indian is of a yellowish brown to a pure brown, much like that of the Malay, and not red. And when the Indians are quoted it should be only with a good ethnological acquaintance with them, and not as a people of one homogeneous culture. They, or at least the great majority of them, must not be classed with the Bushmen and other world's lowest savages. Nor do the Esquimaux deserve such a classing.

There are numerous other points in the book which demand, if not an objection, at least an argument. The space does not permit to mention but two. On page 64 the principal directive motives of the conduct of the primitive man are given as egoism — force — robbery — cruelty — cannibalism; what substantiation can the author bring forth for this singular conception of our ancestors? The second point concerns a notion closely allied, if not the result, of the preceding. It relates to the criminals. Criminals are, for the writer, "from anthropological and psychical view, a return to inferior race" (p. 32); and again (p. 193), "crime is a hereditary (atavistic?) return to a former degree of development of our race, to the epoch when no crime has yet existed." This makes a primitive instead of a defective man out of the criminal!

A. H.

Notes.— Distribution of Blondes and Brunettes in Holland.— In order to obtain some definite data on the distribution of the dark and light types of population in Holland, Dr. Bolk addressed numerous teachers and with their aid secured data on nearly 500,000 children. These data (*Bull. Soc. d'Anthropol.*, ser. 5, vol. 5, p. 578, 1904) show that the dark type is rare in the northern provinces, not exceeding, in many localities, more than ten percent of the population; and that it increases southward, reaching the maximum (40 percent and over) in the provinces of Zeeland, Noord-Brabant, and Limburg. This dark type corresponds, in the opinion of the author, to the brachycephalic "Alpine" type. Among the blondes are recognizable two distinct physical varieties: one, with a longer head and face, best represented in Friesland and corresponding to the "Nordic" or Germanic race; the other, brachycephalic and with a shorter face, found principally in the province of Drenthe, and representing the so called Oriental race of whites. It would be very interesting to have these results supplemented by similar data on Belgium.

Skulls and Skeletons from the Santa Rosa Island, California.—Prof. Matiegka describes (*Sitzungsber. k. böhm. Gesellsch. d. Wissensch.*, 1904, p. 1) in a thorough manner, fifteen crania and four more or less complete skeletons from the Santa Rosa Island. Without going into details it is sufficient to say that the characteristics of the skulls here described agree closely with those of the skulls from the same and neighboring islands, described by previous observers. The majority of the skulls are mesocephalic and with a length-height index ranging principally between 70 and 74. As to the bones of the skeleton, Matiegka's description is the first of its nature from California. The description contains many interesting points for which the reader must be referred to the original. The pelvis is closely related to the European. The radio-humeral index is nearly 79; the tibial-femoral index, 83.5; the relation between the upper and lower limbs, 70.5 (in males).

Cephalic Index in Switzerland.—This communication (*Bull. Soc. d'Anthropol.*, ser. 5, vol. 5, p. 493, 1904) is a brief, interesting report on the form of the head in 587 children, from 10 to 14 years of age, in the Canton of Vaud. The mean cephalic index of the entire series of children was 82.02, corresponding to the index of about 80.02 on the skull. Previous observations by different authors in other cantons gave indexes from 80.6 (Geneva) to 85 (Grisons) and even 87 (a part of Valais), showing that the Swiss population is predominantly sub-brachy- and brachycephalic.

Portuguese Cranial Capacity and Ethnic Composition.—The author (*Bull. Soc. d'Anthropol.*, ser. 5, vol. 5, p. 473, 1904) utilizes the measurements obtained by Macedo, Marques, Basto, and Cardoso, and by their aid, but principally by the data on cranial capacity, attempts to differentiate the Portuguese into several types of people of different origin. According to Macedo's measurements the mean height of the Portuguese in general is, in men, 164.1 cm., mean cephalic index (on skull) 74.5, and mean capacity of the skull (by Broca's method?) 1572 c. c. The main differences are found in the following districts:—

		Stature.	Cephalic Index (Skull).	Nasal Index (Living).	Cranial Capacity.
Traz-os-Montes	(north)	163.3	72.5	66.9	1507 c. c.
Beira Alta	(north)	167.4	72.5	64.6	1596 "
Alemtejo	(south)	166.2	74.8	64.6	1547 "
Minho	(north)	163.8	75.7	64.2	1591 "

Ferreira concludes, on the basis of such differences (but not with-

out taking account of some historic data of invasions), that there exist among the Portuguese two dolichocephalic and three mesaticephalic types of people. Traz-os-Montes population represents one of the dolichocephalic types and that of Beira Alta the other. The population of Minho has been modified by Celtic invasion.

The whole article leaves much to be desired, if not criticised. The data are not always ample enough, even if admitted as homogeneous. The conclusions, and there are many besides those mentioned above, lack a much needed, more-sided, individual corroboration. Nor is the wording always careful enough; the definite term brachycephaly is employed loosely, and so is, to a certain extent, that of mesorhyny.

A. H.

BOTANY.

Leaves of English Forest Trees.[1] — This volume forms the second in the author's series of works on forest trees. It is devoted to an extended treatment of the leaf from several standpoints.

Part 1 of the book is general and concerns itself with the anatomy, morphology, and physiology of the leaf in an elementary way. The subjects of phyllotaxy and venation are given a brief, but lucid treatment. The relation of different forms of leaves to each other is explained by the aid of a few simple mathematical figures. The cell structure of the leaf is treated in a very popular, almost superficial manner. Part of this treatment is very good, but the author endeavors to make it plain by the introduction of dangerously broad analogies.

In describing the physiology of the leaf, the author carries his similies beyond all bounds of necessity or reason. In explaining the processes of metabolism, he attempts to make them realistic by describing the grotesque experiences of an imaginary "traveller" in the tissue of the leaf. After reading the adventures of this traveller during the night, we have the following vivid account of his experiences during the time of day when photosynthesis is going on (p. 92): "In addition to the bombardments of the rushing molecules, our traveller in the passages would also probably perceive violent

[1] Ward, H. Marshall. *Trees. A Handbook of Forest-Botany for the Woodlands and the Laboratory. Vol. II. Leaves.* Cambridge University Press, 1904. 12mo, 348 pp., illustrated.

explosions in the cells as molecule after molecule of carbon-dioxide was torn asunder by the chlorophyll machinery, and would feel or see the walls of the cells heaving in huge oscillations as the moving protoplasmic contents and cell-sap surged under the stress of the chemical forces at work, or of the physical displacements due to the rupture of the molecules and the clashing together of atoms in the course of reconstruction into new groupings."

It is extremely doubtful if the student of forestry, for whom this book is intended, will be helped by such fanciful or roundabout descriptions of important phenomena. If forestry is to be taken seriously, there is no reason why the actual facts should be dressed in such grotesque language. In many ways, however, the discussion is unusually good. The chief error is an apparent overstraining to simplify the subject.

Part 2 of the book is special and is devoted to an analytical key of English forest trees based entirely on the character of the leaves. The descriptions are written with admirable completeness and are unmistakably plain. Although such an analysis throws strangely unlike things together, there is no reason why it should not prove very useful.

The book is one for the amateur student of forestry, but will only be of incidental value to the scientific student.

H. S. R.

Finer Structure of Commercial Timbers.[1]—The object of this book is to enable one to identify commercial woods without the bark, leaves, flowers, or fruit of the tree. The author describes two hundred and forty-seven of the principal commercial timbers of the world. While the descriptions are primarily intended for trade purposes, they will also be of value to the student of microscopic anatomy.

The timbers of trees are arranged in genera and families according to the system of Bentham and Hooker. The following characters are noted for each wood: common names; sources of supply; physical characters (weight per cubic foot, hardness, smell, taste, alcoholic and aqueous solutions, inflammability); grain; bark; uses; color; anatomical characters (pores, rays, rings, pith, etc., in transverse, radial, and longitudinal sections); location of type specimens; and authorities.

[1] Stone, Herbert. *The Timbers of Commerce and their Identification.* London, Wm. Rider & Son, 1904. 8vo, 311 + xxxviii pp., illustrated with 186 photomicrographs by Arthur Deane.

The introduction to the book gives a somewhat technical discussion of the botanical nature of wood and a description of the way in which different woods are formed by growth. Under the title "Practical Hints," directions are given enabling one not skilled with a microscope to identify woods by their structural characters. It also tells how to make and mount thin sections of wood for examination with the microscope or with the stereopticon.

The descriptions are illustrated by one hundred and eighty-six excellently reproduced photomicrographs. The scale of magnification is three times the natural size and is designed to show the appearance of the transverse section as seen by means of an ordinary hand lens.

A good bibliography and index enhance the value of the book.

H. S. R.

A Notebook for the Botanical Laboratory in the High School.[1] — The author has prepared this notebook with special reference to the work outlined in his well known text-books. The book gives comprehensive directions to the pupil for setting up experiments. It contains convenient ruled and blank sheets for the record of results, and there is also ample space for making drawings. It will do much to save time and trouble by minimizing the amount of routine dictation demanded from the teacher. The notebook will help to develop accuracy, self-reliance, and originality in the pupil. It teaches him to be systematic without confusing him with a mass of unnecessary directions.

H. S. R.

Notes.— A paper on fungous diseases of the cranberry, by Shear, forms *Farmers' Bulletin no. 221*, of the U. S. Department of Agriculture.

A popular abridgment of Lovell's papers on colors of flowers is to be found in *The American Botanist*, for March.

An account of the shade trees of Denver forms *Bulletin 96* of the Experiment Station of the Agricultural College of Colorado.

The roots of plants serve as subject for *Bulletin no. 127* of the Experiment Station of the Kansas State Agricultural College, by Ten Eyck.

[1] Bergen, J. Y. *A Notebook to Accompany Bergen's Text-books of Botany.* Boston, Ginn & Co., 1904. 4to, 144 pp.

A paper by Chauveaud on the secretory apparatus of Taxus is published in no. 7 of the *Bulletin du Muséum d'Histoire Naturelle* of Paris for 1904.

Papers on the bamboos are being published by Bureau in current numbers of the *Bulletin du Muséum d'Histoire Naturelle*, of Paris.

Botanically interesting studies of the sand-drift problem in New South Wales are contributed by Maiden and McMaster to vol. 37 of the *Journal and Proceedings of the Royal Society of New South Wales*, recently issued.

An account of aluminum as an important element in certain trees is published by H. G. Smith in vol. 37 of the *Journal and Proceedings of the Royal Society of New South Wales.*

The Journals. — *Torreya*, April: — Harper, "Some Noteworthy Stations for *Pinus palustris*"; Murrill, "Terms applied to the Surface and Surface Appendages of Fungi"; King, "Experiment to show that the Absence of Light alone will Prevent the Process of Photosynthesis"; Parish, "Birds and Mistletoe — a Correction"; Cockerell, "The Name Melampodium."

The Plant World, March: — Nash, "A Trip to the Inaguas" Arthur, "On the Nomenclature of Fungi having Many Fruit Forms"; Streeter, "A Treasure Spot of Wild Flowers"; Wiegand, "The Biology of Buds and Twigs in Winter."

The Ohio Naturalist, April: — Claasen, "Key to the Liverworts recognized in the Sixth Edition of Gray's Manual of Botany"; Smith, "Key to the Ohio Elms in the Winter Condition"; Gleason, "Notes from the Ohio State Herbarium — III"; Riddle, "Development of the Embryo Sac and Embryo of *Staphylea trifoliata*."

GEOLOGY.

Merrill's A Treatise on Rocks, Rock-weathering, and Soils.[1] — This work, which appeared in 1897, was reprinted from electrotype plates in 1904, with an inserted list of errata which apparently the method of reprinting precluded embodying in the text. This work

[1] Merrill, George P. *A Treatise on Rocks, Rock-weathering, and Soils.* New York, The Macmillan Co., 1904. 8vo, xx + 411 pp., 25 pls., 42 text figs. $4.00.

is especially intended to elucidate the formation of soils and surface deposits and as such holds a unique place in special texts for the instruction of students in agriculture and forestry. The chapters on the igneous rocks surpass those in most text books of geology for the general student; and in the field covered by the book the author has done a notable service in informing the general student concerning the important surface changes involved in the weathering of rocks. The work is now so well known to students and teachers of geology that it does not seem necessary to call further attention to the subject-matter of the reprint. It is to be regretted that so important a work should retain so many typographical errors. For this defect the electrotype process, the special character of the treatise, and the probable limited sale of the work, must be held responsible at this time.

J. B. W.

Notes.— "The Geology of the Hudson Valley between the Hoosic and the Kinderhook," by J. Nelson Dale, has appeared as *Bulletin 242*, of the *United States Geological Survey*. This paper serves as a supplement to the work previously published as *Monograph 23* (1894), and gives a series of maps and cross sections from the western Hoosic River to the longitude of Albany.

Bulletin 238 of the *United States Geological Survey* is by Adams, Haworth, and Crane, and has for a title "The Economic Geology of the Iola Quadrangle, Kansas." Nearly three quarters of the report deals with the oil and gas production of this region. The oil and gas are derived mainly from the Cherokee shale, which is the lowest member of the Pennsylvanian, or Lower Carboniferous, series. The character and distribution of the Kansas oil seems to point clearly to an organic origin.

C. W. Wright, after a short visit to Alaska, has extended the knowledge of the placer fields by a description of "The Porcupine Placer District, Alaska" (*Bulletin 236, United States Geological Survey*). In this paper, Mr. Wright points out that the gold found in the placers is mainly derived from local sources, namely, a series of mineralized slates, possibly of Lower Carboniferous age.

"Geographic Tables and Formulas," compiled by S. S. Gannett, *Bulletin 234, United States Geological Survey*, is a reprint with certain additions and corrections of an earlier bulletin (214). The aim of this publication is to afford topographers, both in the field and in the office, a convenient compendium of necessary tables and formulas.

F. G. Plummer and M. G. Gowsell contribute an account of "The Forest Conditions in the Lincoln Forest Reserve, New Mexico." This paper appears as *Professional Paper 33* of the *United States Geological Survey*. The maps and illustrations are particularly interesting to the general reader.

An interesting feature brought out by the map accompanying the report on "The Forest Conditions in the Little Belt Forest Reserve, Montana, and the Little Belt Mountains Quadrangle," by J. B. Leiberg (*Professional Paper 30, United States Geological Survey*), is the large amount of territory that has been deforested by fire. It is estimated that of the 500,000 acres in the reservation 111,000 acres have had the forests destroyed by fire.

Bulletin 258 of the *United States Geological Survey* is a second edition of "Origin of Certain Place Names in the United States," by Henry Gannett. It contains all the notes of the earlier edition (*Bulletin 197, United States Geological Survey*) as well as some fifty-four additional pages.

F. A. Wilder, in "The Lignite of North Dakota and its Relation to Irrigation" (*Water Supply and Irrigation Paper, 117*), presents much interesting matter concerning this fuel. The lignite area, save for two or three outliers, occupies the western portion of the State. In this area, which is nearly half the size of Ohio, there are seams of lignite from an inch up to forty feet in thickness.

Water Supply and Irrigation Paper, 114, "The Underground Waters of Eastern United States," presents a general summary of the ground-water conditions east of the Mississippi River. The waters of each State are treated, either by the State Geologist or by some member of the United States Geological Survey who has made special investigations in the area. Appended to the description of each State is a brief bibliography of the more important papers.

Bulletin 3, Fourth Series, Geological Survey of Ohio, is a volume of 391 pages and 81 figures by A. V. Blaininger on the "Manufacture of Hydraulic Cements." The chapters on "The Analysis and Testing of Raw Materials" and "The Burning of Portland Cements" should be especially useful to hydraulic cement manufacturers and cement chemists.

The work accomplished by the United States Geological Survey for the year 1903–1904 is summarized in the *Twenty-fifth Annual Report of the Director of the United States Geological Survey to the Secretary of the Interior*, published in Washington, 1904. The volume consists of 388 pages, 25 plates, and 2 figures.

A novel way in which vegetation may leave evidence of its existence is described by C. H. White, with illustrations, in the *American Journal of Science* (vol. 19, March, 1905, pp. 231–236). This process consists in the abstraction of coloring matter of the rock on which the plant grows, or the precipitation of coloring matter by the plant. The result of either process is to produce a picture of the plant by the plant itself. For such a picture White proposes the term "autophytograph," and for the process "autophytography."

Professional Paper 31, of the *United States Geological Survey*, is a "Preliminary Report on the Geology of the Arbuckle and Wichita Mountains in Indian Territory and Oklahoma" by J. A. Taft, with "An Appendix on Reported Ore Deposits of the Wichita Mountains" by H. F. Bain. This report, of 97 pages, is well illustrated by 8 plates and 1 figure.

"The Preliminary Report of the Ohio Coöperative Topographical Survey, Nov. 15, 1903," published in Springfield, Ohio, in 1904, gives in its 227 pages a description of the methods employed, and carefully tabulated elevations and positions for the points located by the Survey.

"The Uses of Hydraulic Cement," by F. H. Eno, appears as *Bulletin 2, Fourth Series, Geological Survey of Ohio.* The account is quite popular in style, and the subject matter is of more interest to the constructing engineer than to the geologist. The report treats of hydraulic cements in general, rather than those of Ohio in particular. The following chapter headings suggest the scope of the work: A Brief History of Cement, Uses of Cement in Mortars, Uses of Cement in Concrete, Uses of Cement in Reënforced Concrete, Specification for Concrete Materials, Materials and Tools.

W. M. Davis, in an article on "The Bearing of Physiography upon Suess' Theories" (*Amer. Jour. Sci.*, 4th series, vol. 19, pp. 265–273) adversely criticises the idea that certain plateau-like masses, such as the Schiefergebirge, owe their altitude, not to their own uplift, but to the subsidence of the surrounding lower areas.

C. Davison on "Earthquakes in Mining Districts" (*Geol. Mag.*, no. 491, May, 1905, pp. 219–223) describes three shocks apparently due to the removal of coal or the pumping out of water, which resulted in underground slips along fault planes.

The great Cullinan diamond is described and illustrated by Hatch and Costorphine in the *Geological Magazine* (no. 490, decade 5, vol. 11, pp. 170–171, 1905) in an article entitled "Big Diamond from the Transvaal."

A summary of the laws of the various states regarding underground waters has been prepared by Dr. D. W. Johnson, and published as *Water Supply and Irrigation Paper, 122*, of the *United States Geological Survey*, under the title "Relation of the Law to Underground Water."

The pollution of the water of Lake Champlain by the discharge of waste from pulp mills and sewage has been studied by M. O. Leighton of the United States Geological Survey, and the results of this investigation are published as *Water Supply and Irrigation Paper, 121* — "A Preliminary Report on the Pollution of Lake Champlain."

A valuable bibliography of 628 titles of the different papers on underground water published by the United States Geological Survey during the past twenty-six years, with brief notes on each paper, has been prepared by M. L. Fuller, and published as *Water Supply and Irrigation Paper, 120*.

A valuable paper, entitled "Preliminary Report on the Underground Waters of Washington," has been prepared by the State Geologist, Henry Landes, and published by the United States Geological Survey as *Water Supply and Irrigation Paper, 111*.

An interesting group of fourteen papers has been collected under the title of "Report on Progress of Investigations of Mineral Resources of Alaska in 1904." This appears as *Bulletin 259* of the *United States Geological Survey*, Washington, 1905. The placer deposits are especially well treated.

A continuation of Professor Russell's previous work on the varied and interesting features of the geology of Oregon has recently appeared as *Bulletin 252* of the *United States Geological Survey*, entitled "Preliminary Report on the Geology and Water Resources of Central Oregon," Washington, 1905.

The report of G. C. Martin on "The Petroleum Fields of the Pacific Coast of Alaska," (*Bulletin 250, United States Geological Survey*) shows that the oil is of high grade and of considerable economic promise. It is evident that the oil, which is derived mainly from the Mesozoic strata, contains a high percentage of volatile compounds, has a paraffin base, and a low sulphur content. From analyses made of surface seepage samples, the oil seems to be very similar to that from Pennsylvania.

PUBLICATIONS RECEIVED.

(Regular exchanges are not included.)

Barron, Captain William. Old Whaling Days. London, A. Brown & Sons, Ltd., 1905. 12mo, x + 211 pp.— Duckworth, W. L. H. Morphology and Anthropology. A Handbook for Students. Cambridge Biological Series, London, Macmillan & Co., 1904. 8vo, xxvii + 564 pp., 332 figs.— Gardiner, J. S., ed. The Fauna and Geography of the Maldive and Laccadive Archipelagoes, etc., vol. 2, pt. 4, pp. 807–921, pls. 67–87, text figs. 127–129. Cambridge, Engl., Univ. Press, 1905, 4to.— Gardiner, J. S., ed. The Fauna and Geography of the Maldive and Laccadive Archipelagoes, etc., vol. 2, suppl. 1, pp. 923–1040, pls. 88–C, text figs. 140–153. Cambridge, Engl., Univ. Press, 1905, 4to.— Harmer, S. F., Herdman, W. A., Bridge, T. W., and Boulenger, G. A. The Cambridge Natural History. Vol. 7. Hemichordates, Ascidians, and Amphioxus, Fishes. London, Macmillan & Co., 1904. 8vo, xvii + 760 pp., 440 figs. — McMurrich, J. Playfair. The Development of the Human Body. A Manual of Human Embryology. P. Blakiston's Son & Co., Philadelphia, 1904. 8vo, 2d ed., i–xix, 17–539 pp., 272 text figs.— Overton, F., and Hill, M. E. Nature Study. A Pupil's Text-book. New York, Cincinnati, Chicago; American Book Co., 1905. 12mo, 142 pp., illus.— Peckham, G. W., and E. G. Wasps Social and Solitary. Boston and New York, Houghton, Mifflin and Co., 1905. 12mo, xv + 311 pp., illus.— Sedgwick, Adam. A Students' Text-book of Zoölogy, vol. 2. London, Swan Sonnenschein & Co.; New York, Macmillan Co., 1905. 8vo, xv + 705 pp., 333 figs.— Trouessart, E. L. Catalogus Mammalium tam Viventium quam Fossilium. Quinquennale Supplementum, Anno 1904. Berlin, R. Friedländer & Sohn, 1905. Fasc. 3, pp. 547–752. — Weismann, August. The Evolution Theory. Translated by J. Arthur Thomson and Margaret R. Thomson. London, Edward Arnold, 1904. 8vo, 2 vols., xvi + 416, + 405 pp., illus.

Alexander, A. B. Statistics of the Fisheries of the South Atlantic States, 1902. *U. S. Fish Comm. Rept. for 1903*, pp. 343–410.— Alexander, A. B. Statistics of the Fisheries of the Gulf States, 1902. *U. S. Fish Comm. Rept. for 1903*, pp. 411–481.— Allen, J. A. Mammals from Beaver County, Utah, collected by the Museum Expedition of 1904. *Mus. Brooklyn Inst. Arts and Sci., Science Bull.*, vol. 1, no. 5, pp. 117–122.— Ashmead, W. H. Descriptions of New Genera and Species of Hymenoptera from the Philippine Islands. *Proc. U. S Nat. Mus.*, vol. 28, pp. 127–158, pls. 1–2.— Babor, J. F. Die Weichthiere des bömischen Plistocaen und Holocaen. *Arch. f. naturwissensch. Landesdurchforsch von Böhmen*, vol. 11, no. 5, 78 pp.— Barbour, E. H. Memoir of Wilbur Clinton Knight. *Bull. Geol. Soc. Amer.*, vol. 15, pp. 544–549, pl. 54 — Bather, F. A. *Sympterura minveri*, n. g. et sp.: a Devonian Ophiurid from Cornwall. *Geol. Mag.*, dec. 5, vol. 2, pp. 161–169, pl. 6.— Bleininger, A. V. The Manufacture of Hydraulic Cements. *Geol. Surv. Ohio*, ser. 4, bull. 3, xiv + 391 pp.— Bouvier, E. L. Palinurides et Eryonides recueillis dans l'Atlantique oriental pendant les campagnes de l'Hirondelle et de la Princesse-Alice. *Bull. Mus. Océanographique*

de Monaco, no. 28, 7 pp. — BOUVIER, E. L. À propos des Langoustes longicornes des îles du Cap Vert. *Bull. Mus. Océanographique de Monaco*, no. 29, 6 pp.— BRÖLEMANN, H. W. Symphylés et Diplopodes Monégasques. *Bull. Mus. Océanographique de Monaco*, no. 23, 11 pp.— BRORUP, R. P. The Doctor as an Autocrat. Fitzgerald, Ga., 15 pp.— BUFFUM, B. C. Feeding Experiments with Lambs, 1903–1904. *Univ. of Wyoming Exper. Sta.*, bull. 64, 20 pp., illus. — CARBAJAL, A. J. La fiebre carbonosa. *Comisión de Parasitologia Agrícola*, circ. 17, 4 pp.— CAUDELL, A. N. Orthoptera from Southwestern Texas collected by the Museum Expeditions of 1903, 1904. *Mus. Brooklyn Inst. Arts and Sci., Science Bull.*, vol. 1, no. 4, pp. 105–116, pls. 6–7.— CHEVALLIER, M. Relation entre la densité et la salinité des eaux de mer. *Bull. Mus. Océanographique de Monaco*, no. 31, 12 pp., pl. 2.— CHEVREUX, E. Description d'un amphipode (*Cyphocaris richardi* nov. sp.) provenant des pêches au filet à grande overture de la dernière campagne du yacht Princesse-Alice (1904). *Bull. Mus. Océanographique de Monaco*, no. 24, 5 pp.— CHEVREUX, E. *Cyphocaris alicei*, nouvelle espèce d'amphipode voisine de *Cyphocaris challengeri* Stebbing. *Bull. Mus. Océanographique de Monaco*, no. 27, 6 pp.— CHEVREUX, E. *Paracyphocaris prædator*, type d'un nouveau genre de Lysianassidæ. *Bull. Mus. Océanographique de Monaco*, no. 32, 6 pp., 3 text figs.— CHITTENDEN, A. K. Forest Conditions of Northern New Hampshire. *U. S. Dept. Agric., Bureau of Forestry*, bull. 55, 100 pp., 7 pls., 2 maps.— COBB, J. N. The Commercial Fisheries of the Interior Lakes and Rivers of New York and Vermont. *U. S Bureau of Fisheries, Rept. for 1903*, pp. 225–246.— CONN, H. W. A Preliminary Report on the Protozoa of the Fresh Waters of Connecticut. *Conn. Geol. and Nat. Hist. Surv.*, bull. 2, 69 pp., 34 pls. — CROSBY, C. R. Notes on some Phalangids collected near Ithaca, N. Y. *Jour. N. Y. Ent. Soc.*, vol. 12, pp. 253–256, fig. 4.— DANĚK, J. J. Studien über die Permschichten Böhmens. I. II. III. Umgebung von bömisch Brod, Weaschim und Lomnitz. *Arch. d. naturwissensch. Landesdurchforsch. von Böhmen*, vol. 11, no. 6, 48 pp.— DIMMOCK, G., AND KNAB, F. Early Stages of Carabidæ. *Springfield Mus. Nat. Hist.*, bull. 1, 55 pp., 4 pls.— EDWARDS, H. T. Maguey Cultivation in Mexico. *P. I. Bureau of Agric., Press Bulletin*, no. 1, 5 pp.— EDWARDS, H. T. Abacá (Manila Hemp). *P. I. Bureau of Agric., Farmer's Bulletin*, no. 12, 29 pp., 6 pls.—ENO, F. H. The Uses of Hydraulic Cement. *Geol. Surv. Ohio*, ser. 4, bull. 2, xvi + 260 pp.— EVERMANN, B. W., AND KENDALL, W. C. An interesting Species of Fish from the high Andes of Central Ecuador. *Proc. Biol. Soc. Washington*, vol. 18, pp. 91–106, 2 text figs.— FELT, E. P. Mosquitos or Culicidæ of New York State. *New York State Mus.*, bull. 79, pp. 241–400, 57 pls., 113 figs.— FORBES, S. A., AND RICHARDSON, R. E. On a new Shovelnose Sturgeon from the Mississippi River. *Bull. Ill. State Lab. Nat. Hist.*, vol. 7, pp. 37–44, pls. 4–7.— FREDERICQ, L. La faune et la flore glaciaires du plateau de la Baraque Michel. *Bull. Acad. Roy. Belg., Cl. des Sci.*, 1904, pp. 1263–1326. — FREDERICQ, L. Influence de la température sur la distribution géographique de *Colias palæno* L. Liege, 1 p.—FREDERICQ, L. Note sur la concentration moléculaire des tissus solides de quelques animaux d'eau douce. *Arch. Internat. de Physiol.*, vol. 2, pp. 127–130.— FRIČ, A., AND BAYER, E. Studien im Gebiete der böhmischen Kreideformation. *Arch. d. naturwissensch. Landesdurchforsch. von Böhmen*, vol. 11, no. 2, 180 pp.— FRIČ, A., AND VÁVRA, V. Untersuchungen über die Fauna der Gewässer Böhmens. V. Untersuchung des Elbeflusses und seiner Altwässer. *Arch. d. naturwissensch. Landesdurch-*

forsch. von Böhmen, vol. 11, no. 3, 154 pp., 119 text figs.— FULLER, C. A. The Distribution of Sewage in the Waters of Narragansett Bay, with Especial Reference to the Contamination of the Oyster Beds. *U. S. Bureau of Fisheries, Appendix to Rept. of Commr.*, 1904, pp. 189–238.— GARCIA, F. Onion Culture. *N. Mex. Coll. Agric. and Mech. Arts*, bull. 52, 31 pp.— GARCIA, F. Relation of Frosts and Air Drainage to Fruit Growing. *N. Mex. Coll. Agric. and Mech. Arts*, press bull. 101.— GIFFORD, J. G. The Luquillo Forest Reserve, Porto Rico. *U. S. Dept. Agric., Bureau of Forestry*, bull. 54, 52 pp., 8 pls., 1 map.— GILL, T. On the Systematic Relations of the Ammodytoid Fishes. *Proc. U. S. Nat. Mus.*, vol. 28, pp. 159–163.— GILL, T. The Scorpænoid Fish, *Neosebastes entaxis*, as the Type of a Distinct Genus. *Proc. U. S. Nat. Mus.*, vol. 28, pp. 219–220, 2 figs. — GILL, T. Note on the Genera of Synanceine and Pelorine Fishes. *Proc. U. S. Nat. Mus.*, vol. 28, pp. 221–225.— GILL, T. On the Generic Characteristics of *Prionotus stearnsii*. *Proc. U. S. Nat. Mus.*, vol. 28, pp. 239–342, 4 figs.— GILL, T. State Ichthyology of Massachusetts. *U. S. Bureau of Fisheries, App. to Rept. of Commr. for 1904*, pp. 163–188.— GORDON, C. H. On the Origin and Classification of Gneisses. *Proc. Nebraska Acad. Sci.*, vol. 7, pp. 90–96.— GORDON, C. H. On the Paramorphic Alteration of Pyroxene to Compact Hornblende. *Amer. Geologist*, vol. 34, pp. 40–43. — GORDON, C. H. On the Pyroxenites of the Grenville Series in Ottawa County, Canada. *Journ. Geol.*, vol. 12, pp. 316–325, 4 figs.— GRAVE, C. Investigations for the Promotion of the Oyster Industry of North Carolina. *U. S. Fish Commission Rept. for 1903*, pp. 247–341, 11 pls.— HANAMANN, J. Die chemische Beschaffenheit der fliessenden Gewässer Böhmens. II Theil. Hydrochemie der Elbe. *Arch. d. naturwissensch. Landesdurchforsch. von Böhmen*, vol. 10, no. 5, 100 pp., table.— HANAMANN, J. Über die Bodenbeschaffenheit und das Nährstoffcapital böhmischer Ackererden. *Arch. d. naturwissensch. Landesdurchforsch. von Böhmen*, vol. 11, no. 1, 78 pp., table. — HANSEN, H. J. Preliminary Report on the Schizopoda collected by H. S. H. Prince Albert of Monaco during the Cruise of the Princesse-Alice in the Year 1904. *Bull. Mus. Océanographique de Monaco*, no. 30, 32 pp., 24 text figs. — HARGITT, C. W. The Medusæ of the Woods Hole Region. *Bull. U. S. Bureau of Fisheries for 1904*, vol. 24, pp. 21–79, pls. 1–7.— HATT, W. K. Progress Report on the Strength of Structural Timber. *U. S. Dept. Agric., Bureau of Forestry*, circ. 32, 28 pp. — HAY, W. P. A Revision of Malaclemmys, a Genus of Turtles. *Bull. U. S. Bureau of Fisheries for 1904*, vol. 24, pp. 1–20, pls. 1–12.— HERRERA, A. L. Sur l'imitation des organismes et de la matière vivante avec les solutions pulvérisées de silicati de sodium et de chlorure de calcium. Mexico, 11 pp, illus., 1904.— HERSHEY, O. H. The River Terraces of the Orleans Basin, California. *Univ. of Calif. Publications, Bull. Dept. Geol.*, vol. 3, pp. 423–475.— HRDLIČKA, A. Directions for collecting Information and Specimens for Physical Anthropology. *Bull. U. S. Nat. Mus.*, no. 39, pt. R, 25 pp., 8 pls.— JOHNSON, T. C. Mixtures and Appliances for Spraying. *West Va. Univ. Agric. Exp. Sta.*, bull. 93, pp. 69–118, illus.— JORDAN, D. S. Note on the Salmon and Trout of Japan. *Proc. U. S. Nat. Mus.*, vol. 28, pp. 365–366. — JORDAN, D. S., AND STARKS, E. C. List of Fishes dredged by the Steamer *Albatross* off the Coast of Japan in the Summer of 1900, with Descriptions of New Species and a Review of the Japanese Macrouridæ. *U. S. Fish Commission Bull. for 1902*, pp. 577–630, pls. 1–8.— JORDAN, D. S., AND STARKS, E. C. On a Collection of Fishes made in Korea, by Pierre Louis Jouy, with Descriptions

of New Species. *Proc. U. S. Nat. Mus.*, vol. 28, pp. 193–212.— JORDAN, D. S., AND THOMPSON, J. C. The Fish Fauna of the Tortugas Archipelago. *Bull. U. S. Bureau of Fisheries for 1904*, vol. 24, pp. 229–256, text fig. 1–6.— JOUBIN, L. Note sur les organes photogènes de l'œil de *Leachia cyclura*. *Bull. Mus. Océanographique de Monaco*, no. 33, 13 pp., 7 text figs.— JUDAY, C. List of Fishes collected in Boulder County, Colorado, with Description of a New Species of Leuciscus. *Bull. U. S. Bureau of Fisheries for 1904*, vol. 24, pp. 223-227, 1 fig.— KAFKA, J. Fossile und recente Raubthiere Böhmens (Carnivora). *Arch. d. naturwissensch. Landesdurchforsch. von Böhmens*, vol. 10, no. 6, 120 pp., 55 text figs.— KEARFOTT, W. D. Descriptions of New Species of Tortricid Moths, from North Carolina, with Notes. *Proc. U. S. Nat. Mus.*, vol. 28, pp. 349–364.— KELLOGG, V. L., AND BELL, R. G. Studies of Variation in Insects. *Proc. Washington Acad. Sci.*, vol. 6, pp. 203–232, 81 figs.— KOŘISTKA, K. Das östliche Böhmen, enthaltend das Adler-, das Grulicher- und das Eisengebirge sowie das Ostböhmische Tiefland. *Arch. d. naturwissensch. Landesdurchforsch. von Böhmens*, vol. 9, no. 5, 203 pp., 3 pls.— LAMBE, L. M. A New Recent Marine Sponge (*Esperella bellabellensis*) from the Pacific Coast of Canada. *Ottawa Nat.*, vol. 19, pp. 14–15, pl. 1.— LAMBE, L. M. On the Squamoso-parietal Crest of the Horned Dinosaurs *Centrosaurus apertus* and *Monoclonius canadensis* from the Cretaceous of Alberta. *Trans. Roy. Soc. Canada*, ser. 2, vol. 10, sec. 4, pp. 3–10, pls. 1–2.— LAMBE, L. M. On the Tooth-structure of *Mesohippus westoni* Cope. *Amer. Geologist*, vol. 35, pp. 243–245, pl. 14.— LAMBE, L. M. Progress of Vertebrate Palæontology in Canada. *Trans. Roy. Soc. Canada*, ser. 2, vol 10, sec. 4, pp. 13–56.— LAMEERE, A. L'évolution des ornements sexuels. *Bull. Acad. Roy. Belg., Cl. des Sci.*, 1904, pp. 1327–1364.— LUCAS, F. A. The Osteology and Immediate Relations of the Tile-fish, *Lopholatilus chamæleonticeps*. *Bull. U. S. Bureau of Fisheries for 1904*, vol. 24, pp. 81–86.— LUDOVICO, P. Sulla struttura et sullo sviluppo del rene. Napoli, 34 pp., 24 figs.— LYON, W. S. The Jute Industry considered in Relation to its Introduction to the Philippines. *P. I. Bureau of Agric., Farmer's Bulletin*, no. 11, 12 pp.— MACKAY, A. H. Report of the Botanical Club of Canada for 1903–1904. *Trans. Roy. Soc. Canada*, ser. 2, vol. 10, 17 pp., table.— MACOUN, J. Catalogue of Canadian Birds. Part III. *Geol. Surv. Canada*, no. 883, pp. 411–733, i–xxiii.— MADSEN, T., AND NOGUCHI, H. Toxines et antitoxines. L'influence de la température sur la vitesse de réaction. II. *Bull. Acad. Roy. des Sci. et des Lett. Danemark*, 1904, no. 6, pp. 447–456.— MADSEN, T., AND NOGUCHI, H. Toxines et antitoxines. Saponine-cholestérine. *Bull. Acad. Roy. des Sci. et des Lett. Danemark*, 1904, no. 6, p. 457–464.— MADSEN, T., AND WALBUM, L. Toxines et antitoxines. L'influence de la température sur la vitesse de réaction. I. *Bull. Acad. Roy. des Sci. et des Lett. Danemark*, 1904, no. 6, pp. 426–446.— MEARNS, E. A. Descriptions of New Genera and Species of Mammals from the Philippine Islands. *Proc. U. S. Nat. Mus.*, vol. 28, pp. 425–460.— MEEK, S. E. The Fresh-water Fishes of Mexico north of the Isthmus of Tehuantepec. *Field Columbian Mus.*, zoöl. ser., vol. 5, lxiii + 252 pp., 17 pls., 72 figs.— MERRIAM, C. H. Four New Bears from North America. *Proc. Biol. Soc. Washington*, vol. 17, pp. 153–156.— MERRIAM, C. H. A New Coyote from Southern Mexico. *Proc. Biol. Soc. Washington*, vol. 17, pp. 157–158.— MERRIAM, C. H. A New Sea Otter from Southern California. *Proc. Biol. Soc. Washington*, vol. 17, pp. 159–160.— MERRIAM, J. C. A New Marine Reptile from the Triassic of California. *Univ. of Calif. Publications, Bull. Dept. Geol.*, vol. 3, pp. 419–421,

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THE AMERICAN NATURALIST

A MONTHLY JOURNAL
DEVOTED TO THE NATURAL SCIENCES
IN THEIR WIDEST SENSE

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All naturalists who have anything interesting to say are invited to send in their contributions, but the editors will endeavor to select for publication only that which is of truly scientific value and at the same time written so as to be intelligible, instructive, and interesting to the general scientific reader.

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THE

AMERICAN NATURALIST.

VOL. XXXIX. *November, 1905.* No. 467.

COLLECTION AND PREPARATION OF MATERIAL FOR CLASSES IN ELEMENTARY ZOÖLOGY.

BERTRAM G. SMITH.

DURING the past year the writer has frequently received inquiries concerning methods of collecting and preparing zoölogical material for class use. The purpose of the present article is to give some of the methods used in the Department of Zoölogy of the University of Michigan in supplying a class of over a hundred students with laboratory material for a first course in elementary invertebrate zoölogy. A few organisms are included that are not ordinarily studied in a beginners' course, as some of them may be found useful for demonstrations, or for supplementary work. On the other hand, no attempt is made to make the list comprise all the forms adapted to a first year's course; for many of these, directions for collecting would be superfluous.

1. *Amœba.*[1]— Collect the water plant Ceratophyllum, which will be found growing in the quiet water of ponds and rivers, in the same habitats with water lilies, Elodea, etc. Gather the Ceratophyllum in considerable quantities, packing it in pails

[1] H. S. Jennings. "Methods of Cultivating Amœba and Other Protozoa for Class Use." *Journ. of Applied Micr.*, vol. 6, no. 7, p. 2406.

with enough water to cover. It is best to get material from several localities. If Ceratophyllum cannot be found, Elodea and various other plants may be used, but the results are less satisfactory.

Bring the material to the laboratory and there set up cultures as follows. Use "bacteria dishes" — shallow circular glass dishes, about 9 inches in diameter and 3 inches deep. Pack the material in these *firmly*, crushing it down. This will prevent growth of the plant, and favor fermentation. Pack to within an inch of the top of the dish, and add just enough water to cover the material. Cover the dishes with glass plates and put them in various warm and well lighted places about the laboratory. Each culture should be labeled with the *place* where the material was obtained, and the *date* when the culture was set up. Later, as organisms appear which are to be studied, their *names* should be added to the labels. *Label the dishes, not the covers.* If water evaporates so as to expose the plant material, enough should be added from time to time to make good the loss.

The first cultures should be started about *three weeks* before the Amœbæ are needed. A half dozen cultures should be started at this time and several new ones added every two or three days thereafter, until the class is nearly through studying Amœba. The time required for the cultures to mature varies; a single culture may last but a few days, and not all are successful — hence the necessity for frequent collections and many cultures.

The first indication of Amœba is a brown or a white scum appearing on the surface of the water. This consists mainly of bacteria, and the Amœbæ come to the surface to feed on them. Take up a bit of the scum with forceps, mount in a drop of water taken from the surface with a pipette, tease out the scum thoroughly with needles, and examine with a microscope. Amœbæ, if present, will usually be found among or near the particles of scum. Also, remove a bit of the plant material and scrape the slime from it. This will often contain more Amœbæ than the scum at the surface of the water. The specimens are small at first, but in a few days they become larger.

While the Amœbæ usually disappear from such a culture in a short time, occasionally they persist for a week or more, growing larger. In some cultures they seem to encyst or disappear almost entirely, and later reappear in considerable numbers. Hence old cultures should be watched, and retained until they become overgrown with fungi and hence worthless.

The advantages of the Ceratophyllum method, as described and used by Jennings, are that it gives Amœbæ in abundance, at the time desired, with almost absolute certainty. But the Amœbæ obtained by this method are seldom large; their development is often interfered with and they usually give place to other organisms before attaining maturity. Moreover, the presence of an excessive amount of bacteria and other organisms often obscures the Amœbæ, and makes it difficult to find and study them. To overcome these difficulties, the writer, aided by a suggestion from Professor Reighard, devised a modification of the above method which has proved a valuable supplement to it.

As soon as Amœba appears in the Ceratophyllum cultures, skim off the brown scum with a spoon, and put it in small bacteria dishes about four inches in diameter and one and one half inches deep, with enough water to fill the dish about one inch deep. Add a little of the decaying vegetable material from near the surface of the Ceratophyllum cultures. This should be done several days before the Amœbæ are desired for use. Cover the dishes and keep them in a *warm* place, but not in direct sunlight. In a few days Amœbæ will be found in abundance in some of these cultures, in the scum at the surface or in the ooze and on the decaying plant material at the bottom of the dish. Some of the cultures prepared in this way by the writer gave results far better than were obtained from the ordinary Ceratophyllum cultures; the specimens were remarkably large, active, and numerous. The Amœbæ pass through stages of development and sometimes practically all of them in a given culture encyst at the same time. They may reappear later in an active stage. Later on, among other organisms may appear in these cultures Arcella, Chilomonas, Paramœcium, Vorticella, and occasionally some colonial Protozoa.

2. *Arcella and Difflugia* will often be found in ordinary Amœba cultures, or in cultures made with dead water-lily leaves. In rather fresh cultures, these Protozoa may be found creeping along the surface of the vegetation. Take up a mass of the Ceratophyllum between the fingers and bruise it briskly against a watch glass; add a *little* water to the residue that clings to the glass. It will usually contain Arcella and Difflugia.

3. *Chilomonas* may appear at almost any time in Amœba cultures; but it is best to put up cultures especially for Chilomonas and Infusoria. Use Ceratophyllum and partly decayed water-lily leaves, and pack in bacteria dishes as for Amœba, but use less plant material and more water. Cultures prepared in this way may mature in a very few days. Mount a drop of the water containing Chilomonas, together with a little of the slime or decaying vegetable material by means of which the specimens may be entangled.

4. *Euglena* will appear in some of the cultures put up for Amœba, usually after the disappearance of Amœba, four or five weeks from the date of starting the cultures, but occasionally it appears before Amœba. It makes a solid deep-green (not blue-green) mass at the edge of the dish, especially on the side towards the light. A thick, pale brown, felt-like and granular scum on the surface of the culture seems to be favorable to the presence of Euglena. Such a scum contains delicate fungi, diatoms, desmids, Arcella, etc.

Euglena usually appears in only a few dishes, but in abundance, and lasts several days. Euglena is often associated with Phacus, which somewhat resembles it, but the latter organism is skate-shaped, and does not exhibit euglenoid movements.

Keeping the cultures away from a strong light may prevent the formation of an excess of chlorophyll in Euglena.

5. *Paramœcium.*— Prepare cultures in the same manner as for Chilomonas. Decaying water-lily leaves are especially good. The cultures require but a few days to mature, and last a long time. Mount a drop of water containing Paramœcia, together with a little of the decaying vegetable material about which they may collect.

6. *Vorticella* is often found on decaying duckweed, Riccia, and Ceratophyllum. Place a large handful of the material in a bacteria dish nearly filled with water. Vorticella often appears in cultures prepared for other purposes.

7. *Carchesium* often occurs on water snails and crustaceans amongst duckweed and Riccia. Collect in the same manner as Vorticella.

8. *Volvox* has been found to occur most abundantly amongst duckweed and Riccia, in pools or small ponds that do not dry up. Collect this material by dipping it up together with a little of the water and place a small handful of the material, with some of the water, in each of many bacteria dishes and add enough tap water so that the dishes are nearly full. Place the dishes so that one side is strongly exposed to light. After a few hours, specimens of Volvox may be seen with the naked eye, or with a hand lens, at the water's edge on the lighted side of the dish. Remove them with a pipette to a small covered dish filled with clean water. Volvox kept in clear water and strong light seeks the bottom of the dish, and can readily be found and removed with a pipette when wanted. If left in the original dish, there may be present small crustaceans which will eat them; yet Volvox may sometimes be collected from these dishes for several days. Usually the material yields best after a day or two, and in three or four days becomes worthless. If obtained free from the animals that prey upon it, Volvox may be kept for several days or even longer.

Volvox is not always present in localities that seem favorable for it, and ponds that contain it in abundance are somewhat rare. In some situations it may be collected to advantage by sweeping a bolting-cloth net over water plants, or, better, using a "Birge net," which has a coarse net over the top for keeping out large forms and trash.

Volvox may be preserved in 4 % formalin. Formalin specimens show flagella better than living ones. On account of the uncertainty of obtaining Volvox late in the fall, a supply of preserved specimens should be laid in early in the season.

In studying Volvox, mount the specimens in hollow slides or on ordinary slides with cover-glasses supported by fine glass rods or by bits of broken cover-glass.

9. *Pandorina* sometimes forms a green scum on the surface of the water amongst water lilies, or on the lily leaves.

10. *Hydra* occurs most abundantly on the following plants: duckweed, Riccia, Ceratophyllum, Elodea, watercresses. Two methods of collecting may be used. (a). Method best adapted to duckweed and Riccia: bring in the material with enough water to keep it moist. Fill a large number of bacteria dishes nearly full of clear water. Place in each dish a *small quantity* of the plant material — scarcely enough to cover the surface of the water on which it floats. Place each dish so that one side will be exposed to the light. A day or two later hydras will be found in the extended condition, clinging to the side of the dish, especially the lighted side, to rhizoids of plants, or to dead plants and sediment at the bottom. They may be removed from the sides of the dish with a pipette, or if clinging to plants, the latter may be removed with forceps. Place the hydras in a covered dish of clean water with a small amount of actively growing plant material. Here they will keep indefinitely and may readily be found when wanted. It is not safe to leave them in the original dishes, as there may be present crustaceans which will eat them, or an excess of vegetable matter may cause the water to become foul, which is unfavorable for Hydra. However, the dishes should be inspected daily, for sometimes the material will yield Hydra indefinitely.

(b). When Hydra is to be obtained from large plants like Ceratophyllum and Elodea, the best method is as follows: place a considerable quantity of the plant material in each of several large bacteria dishes and cover it with water. In a short time the water becomes foul through the decomposition of vegetable matter; the hydras then loosen their hold upon the vegetation and may be found floating at the surface of the water. They must be picked off at once with a pipette and removed to clean water.

Hydra will reproduce readily by budding if kept in a fairly warm room; but the optimum temperature is not very high. It is said that if Hydra is kept in the dark at a slightly lower temperature than usual for several days, this will favor the formation of spermaries and ovaries. Rarely, a mature fertilized egg in the winter condition may be found.

11. *Planarians* are found on the under side of stones in running water. They are usually abundant in a locality if found there at all. They may be removed from the stones by means of a thin wooden toothpick, and placed in a bottle of water for transportation.

12. *Earthworms.*— The *collection* of earthworms should be attended to as early in the fall as possible, as dry or cold weather may make it impossible to get them later. It is well to lay in a supply of preserved worms during the spring or summer. Specimens to be kept alive should perhaps not be collected until after the first of October, but it will be unsafe to wait much longer. Each student will need two or three preserved, and one or two living specimens.

The form used in the Zoölogical Laboratory of the University of Michigan is *Lumbricus herculeus* Savigny. The specimens range in length from about 6 to 11 inches, with an average of about 8 inches. They come out of their burrows on warm, rainy nights, usually lying extended with the posterior end of the body still in the entrance of the burrow. They are most abundant in old, rich gardens and lawns. Go out with a lantern and a pail after it has become quite dark; the harder it rains the better. By stepping lightly and not allowing the light to shine upon them too long, one may seize the worms with the hand. To catch them requires quickness and dexterity; but they must be pulled gently from the burrow.

When brought into the laboratory the worms that are to be preserved for dissection should be placed immediately in covered bacteria dishes (9 inches in diameter by 3 inches deep) between sheets of moist filter paper; the covers should be adjusted so as to admit a little air. Not more than twelve specimens should be placed in a dish, as they will soon die if large numbers of them are left together. The dishes should be kept in a cool place, avoiding direct sunlight. In the morning the paper should be changed, and injured or dead specimens removed; the operation should be repeated as often as is necessary. After a day or two the worms will have eaten enough moist filter paper to clean the alimentary canal of earth, and are ready for preservation.

Worms to be kept alive for a considerable length of time[1] may be placed, immediately after collection, between folds of moist muslin in bacteria dishes, with not more than a dozen specimens in a dish. Change or wash the cloth occasionally — at least every two weeks. The worms may be fed on leaves, etc., if desired. With proper care, they will keep in this way for months, and are always clean and ready for use at a moment's notice. The writer has found that the worms will keep quite as well if filter paper is used instead of muslin.

Preparation of Earthworms for Dissection.— Fresh specimens are too soft for convenient handling of the tissues during dissection; it is also inconvenient to keep a sufficient number of them alive for general dissection purposes; hence preservation is resorted to. Two methods are available: —

(*a*) *Chromic Acid Method.*

1. *Killing.*— Place in 4% alcohol and gradually increase the strength to 8% in the course of the next two hours by adding stronger alcohol a few drops at a time. Wash in water to free from mucus and again immerse in 8% alcohol until the worms are thoroughly stupefied and no longer contract when pinched with forceps.

2. *Fixing.*— Inject worms with 1% chromic acid and immerse in the acid for about 4 hours.

The injection is best performed by means of a water pressure apparatus (see Fig. 1). This gives constant, uniform pressure. A head of about four feet of water should be used. A glass cannula may be made by drawing out the end of a piece of $\frac{1}{4}$ inch glass tubing to a very fine bore, and breaking it so as to leave a sharp point with a raw edge. The exact size must be determined by experiment. The stream may be allowed to flow continuously from the cannula. A pipette with point drawn out fine may be used in case this apparatus is not available, but it is not very satisfactory.

[1] H. S. Jennings. "Keeping Earthworms Alive in Winter." *Journ. of Applied Micr.*, vol. 6, no. 7, pp. 2412–2413.

Fill a large shallow glass dish about $\frac{1}{2}$ inch deep with 1 % chromic acid. (Cover the hands and wrists thickly with vaseline while working with chromic acid.) Take each worm separately and lay it in an extended condition in the chromic acid, keeping it straight and seeing that it is not twisted. Inject immediately,

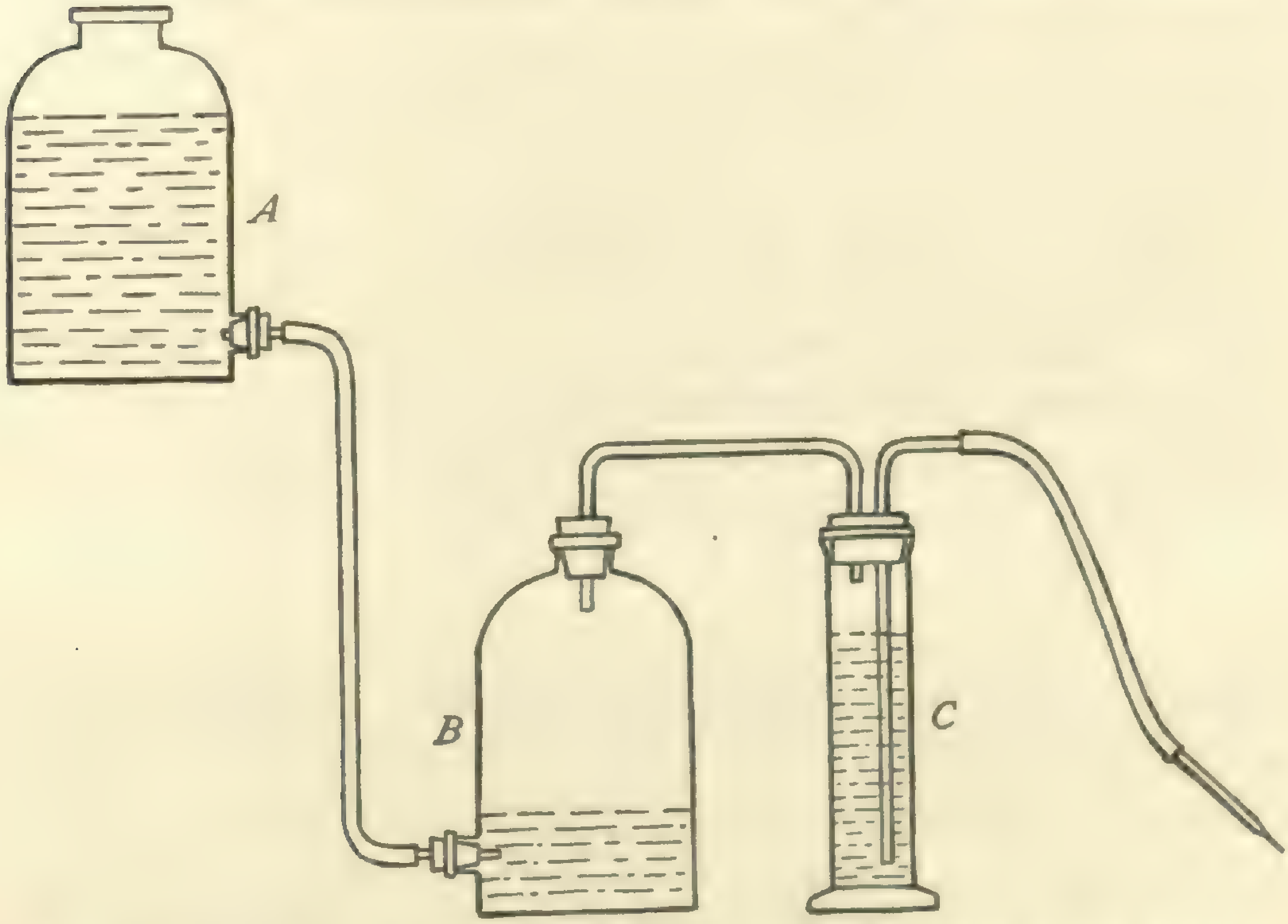

FIG. 1.— Constant pressure injection apparatus. *a* should be filled with water, part of which flows into *b*; *c* contains injection fluid.

about $\frac{1}{2}$ inch behind the clitellum, and again near the posterior end of the body if necessary. *Inject into the body cavity; be careful not to pierce the alimentary canal.* The worm should swell out slowly along its entire length and become very turgid. Too rapid injection may tear the tissues.

The worms should be kept straight while in chromic acid. If left in the acid less than four hours they will eventually become too soft; if left in the acid much more than four hours they will be too brittle.

Wash thoroughly in running water until the yellow color is gone — about 12 hours. Be sure that the water reaches every part of the surface of each worm. If free acid remains on the worms it will make them brittle. The worms are a light drab, not yellowish brown, when well washed.

3. *Preserving.*— Place the worms in 50 % alcohol and leave for a day or two; the alcohol will become discolored by chromic acid. Change to 70 % and leave a day or two longer. Then change to the same grade (70 %) for final preservation.

The alcohol will complete the process of removing free acid and will further harden the tissues. Stronger grades of alcohol than 70 % are not advisable for preservation, as they may cause the more delicate tissues to become brittle.

(*b*) *Alcohol Method.*

Kill as directed under chromic acid method. Place the worms in 50 % alcohol, keeping bodies as straight as possible. Leave 4 or 5 hours, then place in 70 % alcohol and leave over night. Next morning place in 96 % alcohol to harden them, and leave all day. Change to 70 % alcohol for final preservation.

Choice of Methods.— Specimens hardened in chromic acid are most satisfactory for general dissection purposes. The tissues are firm and leathery, and are not affected by water during dissection, hence they may be dissected under water instead of alcohol. This is a decided advantage. The largest and best marked specimens should be put up in this way.

The alcohol method of fixing is not so satisfactory for most purposes; the body wall and tissues generally are too soft to be conveniently handled unless the dissection is done under alcohol. But the method has the advantage of simplicity, and the smaller and more poorly marked specimens may be put up in this way for use in case other material runs short. Alcoholic specimens do very well for the study of the nervous system.

Fresh specimens are not only necessary for the study of the living worm, and for demonstrations of cilia, blood, cœlomic fluid, spermatozoa, etc., but are best for the study of the circulatory system and the nephridia.

For studying the circulatory system the living specimen may be stretched out in a dissecting tray and fastened with a pin through each end of the body; if desired it may first be stupefied with alcohol. The dissection should be carried on under

normal salt solution (0.75 % NaCl). In the absence of living specimens, chromic-acid specimens do fairly well for the circulatory system.

For sectioning with a microtome it is necessary to have specimens with intestines entirely free from grit. Worms that have been kept in clean, moist muslin for a considerable length of time will usually be found to have the alimentary canal free from all undesirable substances. The muslin should be changed every day, and the worms must not be fed. A quicker method [1] is to flush the alimentary canal by means of an injection apparatus. Use a cannula with a rather large opening; the proper pressure must be determined by experiment. Stupefy the worms with dilute alcohol (3 to 6 %). Inject the alimentary canal from the posterior end with 0.75 % salt solution; roll the body of the worm back of the clitellum between the fingers and strip out the contents of the intestine. Then inject from the anterior end; this time the stream will go entirely through. Avoid too much pressure, as it will injure the tissues. Roll and knead the body while the stream is being started through. The fluid should be forced through the worm until it comes from the posterior end in a perfectly clear stream. The worm is then ready for fixing.

Zoölogical Laboratory, University of Michigan,
Ann Arbor, Mich.

[1] Raymond Pearl. *Journ. of Applied Micr.*, vol. 3, no. 1, p. 680.

A NEW OSTRACOD FROM NANTUCKET.

JOSEPH A. CUSHMAN.

During the spring of 1905, several members of the Nantucket Maria Mitchell Association made collections from the various bodies of fresh water on the island. This material was kindly turned over to me for study. Among other noteworthy things is an ostracod of the genus Cyprinotus that is apparently new. Its description follows: —

Cyprinotus americanus sp. nov.

Plate 1, Figs. 1–8.

Length of male 1.5 mm., width 0.7 mm., height 0.8 mm.

The length of the shell is a little more than twice the width and the height is slightly greater than the width. The shell is thin, translucent, free from bands or color markings of any sort (Pl. 1, Fig. 1).

Viewed from the side (Pl. 1, Fig. 1) the shell is suboval, with the greatest height slightly more towards the cephalic end. The dorsal margin is convex, the cephalic end much more convex than the caudal, which is almost bluntly pointed. The ventral margin is also slightly convex.

Viewed from above (Pl. 1, Fig. 2) the shell is narrowly elliptical with the anterior end more rounded than the posterior.

The third joint of the antenna is toothed on the distal part of each side, with one of the angles clothed with fairly long hairs. The single seta from this angle is doubly fringed. The last joint is short and bears two of the four terminal claws, these latter being finely toothed. The natatory setæ extend to the end of the terminal claws. The characters of the antennules are shown in Fig. 4 (Pl. 1). The setæ from the last joint are much shorter than those from the preceding ones. The characters of the mandible are very distinctive. The setæ of the upper joint are peculiar, all of them being doubly fringed with scattered hairs. The large terminal setæ are fringed on a single side. The third joint has many short spines on its ventral side. The jaw of the mandible has compound teeth of which the anterior ones are comb-like in structure.

The first foot has a long terminal claw the distal part of which is finely toothed. The fourth joint bears four short spines. The second joint has

two long curved spines in addition to the setæ. The second foot has a peculiar claw-like extremity. The last joint is constricted in the middle and the distal portion bears two rows of minute spines.

The rami of the postabdomen have two long claws, finely toothed along their whole length. The proximal small seta is considerably removed from the others.

Habitat. — Specimens collected from Grove Lane Ditch near the town of Nantucket, Mass., April 30, 1905, by Miss Marianna Hussey.

In many ways this species most closely resembles *C. burlingtonensis* Turner but is different in its proportions and in the distribution of the setæ on the appendages as well as in their spinosity, and the shape and setæ of the mandible.

PLATE I.

Fig. 1.— Shell viewed from the side. × 40.
Fig. 2.— Shell viewed from above. × 40.
Fig. 3.— Antenna. × 200.
Fig. 4.— Antennule. × 200.
Fig. 5.— Mandible of another species placed on this plate by mistake.
Fig. 6.— First foot. × 200.
Fig. 7.— Second foot. × 200.
Fig. 8.— Abdominal rami. × 200.

FURTHER NOTE ON *HYLA ANDERSONII* AND *RANA VIRGATIPES* IN NEW JERSEY.

WILLIAM T. DAVIS.

In Cope's *Batrachia of North America*, and in other works treating of our native frogs, *Hyla andersonii* Baird is said to be rarely met with. In the note on this species by the writer published in the *American Naturalist* for November–December, 1904, that view was also taken, but it must now be accepted as a fact that *Hyla andersonii* is anything but a rare frog in certain parts of the New Jersey pine barrens.

At Lakehurst, New Jersey, especially in the latter part of May and in June, there may be heard at evening coming from the white cedar swamps, many voices that resemble the familiar quacking of ducks. If one will take the trouble to wade into one of these swamps at twilight and approach the singer cautiously, it will be discovered that he is a male *Hyla andersonii*. He pipes up and sings "*aquack-aquack-aquack*" many times, or until his bubble of air gives out. This is the time, while he is singing, to take a step forward. Even when the observer is very near and evidently plainly in his view, he cannot resist the temptation to sing, for he hears his rivals all about calling loudly. The notes are not all alike in sound, and some individuals remind one of the "*potrack-potrack*" of the farmyard Guinea fowl. The Hyla will be found seated on the lower limb of some tree, or among the top branches of a huckleberry bush. I have heard this frog singing at mid-day when the sun was shining brightly, especially after a shower. Also solitary individuals may be heard in the swamps much later in the year, and they do not appear to wander as far from the water as does *Hyla versicolor*.

Rana virgatipes Cope is also more abundant at Lakehurst than at first supposed, and has been found from May to September. In the early summer as many as twelve have been seen in one day without much search having been made for them.

They are apt to be in some ditch and seated on the sphagnum moss, or on a floating lily pad, and they are found also in the ditches that border and intersect the cranberry bogs, as well as in the lake.

A SYSTEMATIC STUDY OF THE SALICACEÆ.

(*Concluded.*)

D. P. PENHALLOW.

Anatomy.

The Growth Rings.—So far as may be judged from an examination of fifteen species of Salix and eleven species of Populus, growth rings of somewhat great radial extent appear to be a general characteristic of the Salicaceæ. Such a feature is directly correlated with, and in fact may be taken to be a resultant of the very free growth for which the members of this family are, in general, conspicuous. Partial exceptions have been observed in the medium growth rings of *Populus balsamifera*, *P. monilifera*, and *P. heterophylla*, as also of *Salix scouleriana*; but slight deviations of this nature cannot be regarded as expressing a general law, since as has been shown by Peirce (:04), they may well have arisen in response to injuries inflicted by insects or other agencies, or they may simply be an expression of periodicity in climatic conditions. The same statement cannot be said to hold true in equal measure of *Populus alba* and *P. grandidentata*, since in both of these species the generally narrow and uniform growth rings seems to point to specific differences. These observations are greatly strengthened by the fact that *Salix uva-ursi* presents a noteworthy deviation from the general characteristics of the family. Its growth rings are not only narrow, but they are variable and strongly eccentric. Such characteristics are very readily understood when the natural habitat of this plant is recalled. Growing in the Alpine Garden on Mt. Washington at an elevation of about five thousand feet, its development is accomplished under the influence of a very short season the character of which must vary in an exceptional manner from year to year, while the prostrate habit would also establish marked eccentricity of

growth. This case is therefore to be regarded as lying outside the normal course of development for the family as a whole, while at the same time it serves to give emphasis to the specific effects of external influences in modifying the character of the growth.

It is a general feature of the Salicaceæ to which there are no well defined exceptions of a noteworthy character, that there is substantially no differentiation of spring and summer wood. Partial exceptions seem to be shown by *Salix longifolia* in which the last six rows of cells sometimes become radially compressed, or by *S. cordata* and *S. lævigata* in which three rows are sometimes so modified. The fact that in all these cases the modification is not a constant feature, but that it arises sporadically, indicates clearly that it is due to some exceptional and transitory influence, and that it does not in any way express the usual characteristics of growth. On the contrary, it is not an uncommon feature in *S. nigra* for the first half of the growth ring to present the most dense structure, this being due, not to a diminution of the vessels with a relative preponderance of the fibrous mechanical cells, but to the fact that the latter are characterized by thicker walls than elsewhere, with a corresponding diminution of the cell cavity. In the investigated species of poplar, there seems to be no deviation from the general rule thus expressed. In both genera there is substantially no alteration in the form and size of the wood cells as between those of the inner and those of the outer face of the growth ring (Figs. 6, 7), and the demarcation between the growths of successive seasons is determined by other factors of which the occurrence of a limiting zone of resinous wood parenchyma is the most important. From these considerations it appears that the character of the growth ring, in its more general aspects, possesses no diagnostic value for specific purposes, or even for generic differentiations, but that it may be regarded as of value for ordinal purposes with respect to their great breadth and the absence of any marked differentiation between the spring and summer woods. Since the radial compression which is generally so distinctive a feature of the summer wood, is recognized to result from increasing cortical pressure (De Bary, '84, p. 501) it must

be inferred from the observed structural conditions, that in the Salicaceæ as a whole, the bark expands or ruptures in such a way as to provide a minimum of pressure which is practically uniform during the entire period of growth.

The Transition Zone.— The protoxylem region in the Salicaceæ, or what may with more propriety be termed the *transition zone* in accordance with the previous use of that term (Penhallow, :00, :04c), is exclusively confined to the growth of the first year in accordance with the general law of growth which governs the Dicotyledonous angiosperms, and the following observations must therefore be interpreted in that sense.

So far as our studies have gone, they show that in the arborescent Salicaceæ, whether Populus or Salix, the transition zone is narrow and that it consists almost exclusively of a few spiral and scalariform elements. I have as yet been unable to discover in such forms, any extension of the protoxylem which would admit of transitional forms of the elements. The transition from the primitive protoxylem elements on the one hand, to completed forms of wood cells without pits, and of broad vessels with hexagonal pits on the other hand, appears to be developed with great abruptness. These features appear to be so well defined and constant as to make it apparent that the transition zone has been so far reduced as to approach the point of actual extinction.

In 1897 an opportunity was presented to collect some stems of *Salix uva-ursi* from the Alpine Garden, Mt. Washington. At that elevation the greatly reduced shrubs are forced to assume a prostrate habit of growth, in consequence of which the rather slender and somewhat sinuous stems are buried under a considerable accumulation of plant *débris*. In such situations, although there is usually an abundance of water during the summer, the plant is of a somewhat xerophilous habit as made evident by the reduced and somewhat coriaceous foliage, in obedience to the low temperature and the consequent inability of the roots to provide for an actively moving transpiration current, as pointed out by Schimper (:03). This xerophilous habit is also expressed in the general structure of the wood as may be observed by reference to the diagnosis, from which it will be

noted that the vessels are very small and there is a relative preponderance of the mechanical tissue. Assuming that the willows originated under the influence of a relatively warm climate as we have reason to believe must have been the case on the basis of evidence brought forward by Wieland (:03), it is evident that *Salix uva-ursi* in common with other boreal and alpine forms, must represent a degenerate type which has been reduced under the influence of a diminishing temperature. But such reduction has clearly involved a loss of the originally erect position, and in consequence of the diminished necessity for mechanical support, it might be inferred that there would be a more or less pronounced tendency to reversion in such wise that the transition zone would tend to regain its primitive character to some extent, and that it would once more exhibit those developmental features of structure which have essentially disappeared from the great majority of species as now known. It was therefore felt that this plant might offer exceptional opportunities for a solution, in part at least, of the question as to the actual genesis of the vessels and the wood cells, and their mutual relations. The stem selected for study was of a somewhat sinuous form and in cross section ovate, the diameters being 1.20 and 1.80 cm., with the pith eccentrically placed toward the narrower or under side, the major axis of the cross section being oriented vertically. Longitudinal sections were cut from this stem at a slight angle with its principal axis, and in such number as to embrace not only the entire pith, but a considerable portion of the secondary xylem lying on opposite sides. It will thus be observed that while some of the sections were strictly radial, their character gradually changed as the relation of the plane of section to the radius changed, until they became strictly tangential. It thus became possible to study the elements of the transition zone from these two points of view and in a progressive series. But owing to the slight inclination of the plane of section to the longitudinal axis of the stem, the same section would exhibit at one end the radial aspect and at the other end the tangential aspect, while between the two there would be a graduated series of changes showing all details in the entire radial extent of the transition zone. This

was found to be of special importance because the protoxylem is so localized and forms such small groups, while the transition elements are so scattered, that many radial sections might be examined without furnishing conclusive results. The diagonal plane of section, on the other hand, cuts through the entire radial extent of the transition zone and is certain to display whatever transition forms may be present. In this way it was possible to obtain the figures now presented.

The rather scanty pith is composed of isodiametric and somewhat thick-walled cells of large size, which, at the periphery, become greatly reduced in size without any diminution of the absolute thickness of the walls, assume the form of short cylinders, and function as resin-bearing parenchyma. There is thus produced a strongly resinous zone of tissue in immediate contact with the protoxylem and enclosing it on the radially inward face as well as the two tangential faces. It is not difficult to determine that the protoxylem consists primarily and chiefly of the usual spiral and scalariform tracheids which are common to the same zone in others of the Salicaceæ; but a careful examination of the diagonal section shows that there are other elements of a transitional character not to be met with, so far as I am aware, in other species having an upright habit of growth. A somewhat detailed account of the features noted will be essential.

The protoxylem elements proper consist of a few spiral tracheids characterized by very flat and close spirals. Such elements commonly have very abrupt and often transverse terminations. The length varies very much, so that while in most cases long, they are also not infrequently very short. As exposed in section on the tangential walls, the spirals are seen not to be simple bands, but to be broadest in the part which was most recently formed, and therefore most remote from the primary wall. The general effect of this is to give to the sectional view of the wall, the appearance of a continuous series of contiguous, bordered pits. This fact also makes it clear that the spirals of Salix have lost the simple and primitive character of those bands which are to be met with in the protoxylem of the gymnosperms, or even in many of the vessels of the Monocotyledons, and that they

have distinctly approached that modification which must immediately precede the formation of bordered pits. Such a feature serves to show that the transition from spiral to scalariform structure might be accomplished without any very conspicuous transitional forms such as have been shown to exist in the case of Cordaites, and such as are found not to exist in the Salicaceæ as a rule; while it also serves to explain in part the great radial diminution of the protoxylem of the Salicaceæ as compared with that of more primitive forms of plants. In addition to the spiral tracheids, the protoxylem also includes a certain number — generally few — of scalariform elements. These approximate in form and size to the spiral tracheids though they often have distinctly tapering extremities, in which respect they approximate very closely to the fibrous mechanical elements or wood cells of the secondary xylem (Fig. 1). It has also been observed in such cases, that the scalariform markings become distinctly fewer and more distant (Fig. 1) as if certain of the pits had been obliterated by a more general secondary thickening of the wall, and that such is the true explanation we are justified in believing from a study of the transition zone in Cordaites (Penhallow, :00, :04c). That such obliteration has not proceeded at a uniform rate throughout the length of the cell, is evident from the figure given. When such scalariform markings are exposed in section, they exhibit precisely the same bordered structure as in the case of the spirals. The most interior portion of the secondary xylem sometimes contains scalariform elements of a transitional form. In such cases the scalariform structure is irregular and very imperfectly developed upon both the radial and the tangential walls, presenting an obvious form of transition in the direction of the bordered pits, chiefly expressed in the shortening of the individual pits and their more definite segregation. But such changes in the structure of the cell wall might equally well be precedent to the complete and final obliteration of the pits of whatever form,

Fig. 1.— *Salix uva-ursi*. Tangential section of a scalariform tracheid showing transitional form. × 350.

a view which is justified not only by the reduction in size and number of the scalariform markings, but by the irregular manner in which such reduction proceeds, so that the pits often lack that regular and definite disposition so characteristic of the bordered pits; and finally it is justified by the fact as shown in Fig. 1, that the scalariform markings are often wanting on the radial walls while characteristically developed on the tangential walls.

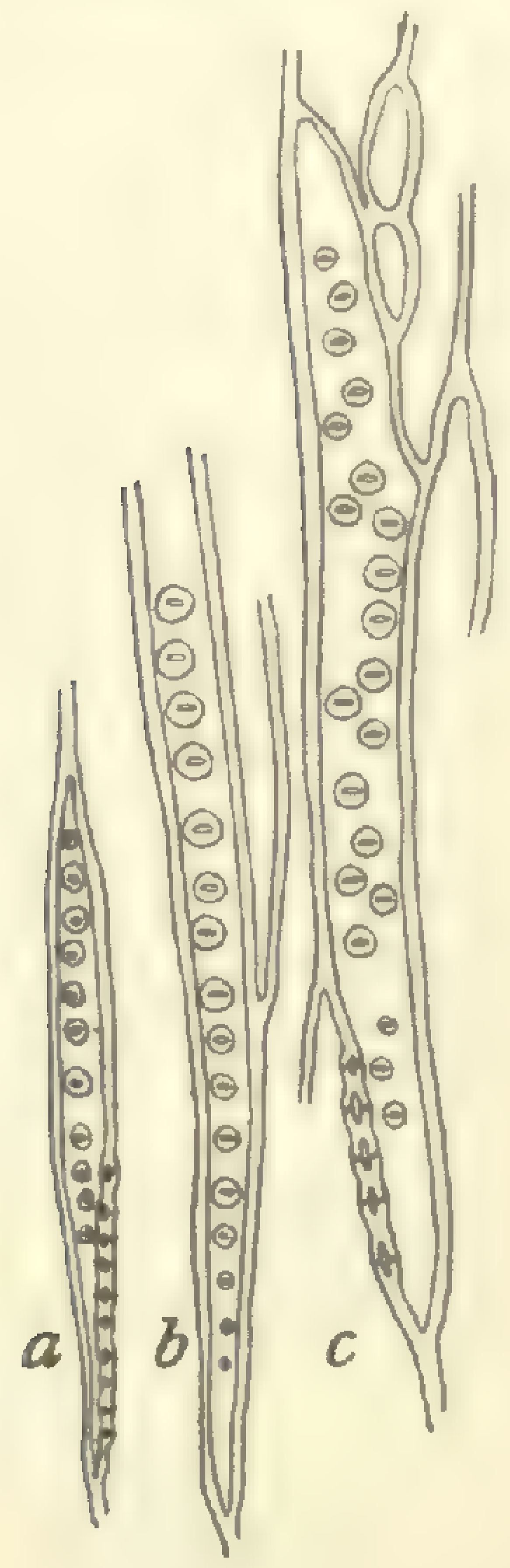

FIG. 2.—*Salix uva-ursi.* Tangential sections of tracheids with bordered pits, showing transitional forms in the direction of fibrous wood cells. × 350.

The earliest secondary xylem is characterized by the presence of true fibrous tracheids distinguished by the presence of bordered pits. These tracheids as shown in Figs. 2 and 3, are all tapering or of the fibrous and fusiform type, and they vary very much in length and breadth. In those of the most slender form, there is but a single row of bordered pits which diminish very greatly in size as the end of the tracheid is approached (Figs. 2, *a*, *b*). With an increase in breadth and usually a corresponding diminution of length (Fig. 2, *c*), there is a strong tendency to a multiseriate arrangement which becomes fully expressed in the completely developed vessel as shown in Fig. 5. In such fibrous tracheids, there is considerable variation in the distribution of the bordered pits. Thus we find many instances of pits on both the radial and tangential walls (Fig. 3), a distribution common to the vessels as shown in Fig. 5, although it will be noted that when such a vessel abuts upon a fibrous wood cell, there are no bordered pits on the radial wall common to the two. This fact is expressed in other ways. Thus in the case of the fibrous tracheids in Fig. 2,

FIG. 3.—*Salix uva-ursi.* Tangential section showing transitional forms of tracheids with bordered pits on both the radial and the tangential walls, and resinous wood cells. × 350.

it will be seen that the pits are confined chiefly to the tangential walls, and appear on the radial walls at the ends only of the tracheids (Figs. 2, *a*, *c*), or they may even be completely eliminated from the radial walls as in Fig. 2, *b*. Such variations are also to be seen in Fig. 4. One variation of such relations worthy of note, was found in radial section. A spiral tracheid of the protoxylem was immediately followed on its outer side, by a fibrous tracheid with round, variably distant bordered pits in one series. The tangential wall common to the two was also provided with a continuous series of bordered pits. Immediately outside the fibrous tracheid, and therefore on the side opposite the spiral tracheid, was a fibrous wood cell presenting no pits of any kind upon either its radial or its tangential walls. The illustrations thus given in detail, serve to illustrate the general fact that all sorts of transitional forms are to be found, connecting the fibrous elements of the secondary xylem with the cylindrical and more or less tubular elements of the protoxylem; and it is quite evident that we have in *Salix uva-ursi* the same sort of a transition zone as that which has already been shown to exist in the gymnosperms (Penhallow, :00), the two cases differing chiefly with respect to (1) the radial extent of the zone, (2) the number and extent of the transition forms, and (3) the specific character of the final products. When we consider the various transformation stages occurring in *Salix uva-ursi*, the peculiar conditions of reduction in the structural details of the cell wall, the special alterations in the form of the individual elements, and the peculiar association of these derived forms, it is exceedingly

FIG. 4. — *Salix uva-ursi*. Tangential section showing various phases in the evolution of the fibrous wood cell through the pitted tracheid. × 350.

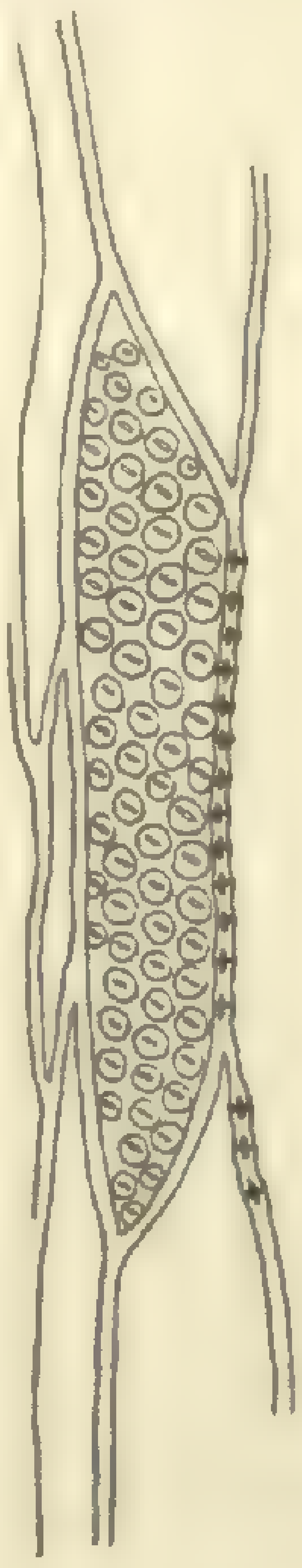

FIG. 5. — *Salix uva-ursi*. Tangential section of a vessel showing its relation to fibrous wood cells, the multiseriate bordered pits on both radial and tangential walls, and its deviation from the type of the fibrous tracheid. × 350.

difficult not to feel that we have before us an expression of evolution in two directions from the protoxylem, the one leading directly to the formation of vessels with multiseriate bordered pits; the other leading to the formation of purely mechanical and fibrous elements wholly devoid of pits, or in which the latter survive in the form of simple, sporadic perforations of small size. As far as it is possible to interpret the alterations of structure so far observed, the following would seem to be the sequence of events: —

Protoxylem.

Spiral tracheids with close spirals set at a low angle and showing a bordered pit structure in section. Terminations usually abrupt.

Scalariform tracheids with abrupt or tapering extremities; the markings showing a bordered pit structure in section. Transitional forms numerous. Markings often obliterated from either the radial or the tangential walls.

Secondary Xylem.

The elements diminish in length and increase in breadth.

The bordered pits on both the radial and the tangential walls are successively 1-, 2-, and multiseriate.

The vessels thus formed are multiplied in large numbers; they serve the purpose of circulation; they are reproduced as features of the secondary wood of each year's growth; they do not form a definite zone or medullary sheath after the first year; their functional activity may be arrested by the excessive development of thyloses or other causes; they constitute a relatively small portion of the entire structure; they contribute to the greater porosity and diminished strength of the structure as a whole.

The elements diminish in breadth and increase in length.

Bordered pits are at first present on both the radial and the tangential walls; at first one-seriate, they diminish in number and become more strictly segregated; they become more strictly confined to the radial walls: they eventually disappear: the secondary wall becomes of uniform thickness throughout, rarely with simple and minute pits. The mechanical elements or wood cells thus formed, are concerned solely with meeting the requirements of stress, to which end they are especially adapted; they constitute the chief part of the secondary xylem as of the secondary growth of the stem, to which they impart hardness, solidity, rigidity, and durability.

A comparison of these evolutionary phases with those already determined for Cordaites (Penhallow, :00, p. 57, and :04c, p. 250) will show that the two are essentially parallel, differing from one another only in detail in the two directions already indicated. So far then as the Salicaceæ are concerned, there is abundant supplementary evidence to show that in that family as well as in the gymnosperms, the evolution of the secondary xylem from the protoxylem is determined by the special requirements of support and the movement of the transpiration current; that the fibrous, non-pitted wood cells serving the ends of mechanical support, are derived from the spiral tracheids in the first instance; and that the relative predominance of mechanical or conductive tissue, is the *resultant* of influences acting along two distinct lines of development.

The Wood Cells.—Very little diagnostic value attaches to the appearance or disposition of the wood cells as presented in transverse section, and such features as they do exhibit are rather of ordinal than of generic or specific value. They are always hexagonal and very variable as to size. Usually they are disposed in a very irregular manner, though occasionally there is a more or less pronounced tendency to disposition in radial rows, but in no case is this so pronounced as in the Coniferæ — a difference which may be said to distinguish the gymnosperms from all the higher types of woody plants. The walls are of medium thickness, a feature which seems to be consistent with the generally soft character of the woody structure, and, as already pointed out, there is a complete absence of that unequal, regional, secondary growth of the cell wall which, in other woods, contributes so largely to a differentiation of the spring and summer woods. On the whole, the structure of the mechanical tissue is closely comparable with that of the Rhamnaceæ, a resemblance which will be found to extend to other features of the vascular zone.

Wood Parenchyma.—In its transverse section, the wood parenchyma varies considerably according to its position in the structure. Within the region of the medullary sheath the elements are more or less isodiametric; when associated with vessels, the tendency is to compression conformably with the

radius of the vessel; when forming isolated tracts, they tend to assume the form of the associated wood cells; but when occurring in the limiting zone of a growth ring where they are chiefly to be met with, they are invariably compressed in a radial direction, thereby assuming a form which serves to distinguish them from the associated mechanical elements.

In their longitudinal aspects there is little that is not common to such elements wherever they may be found. They are cylin-

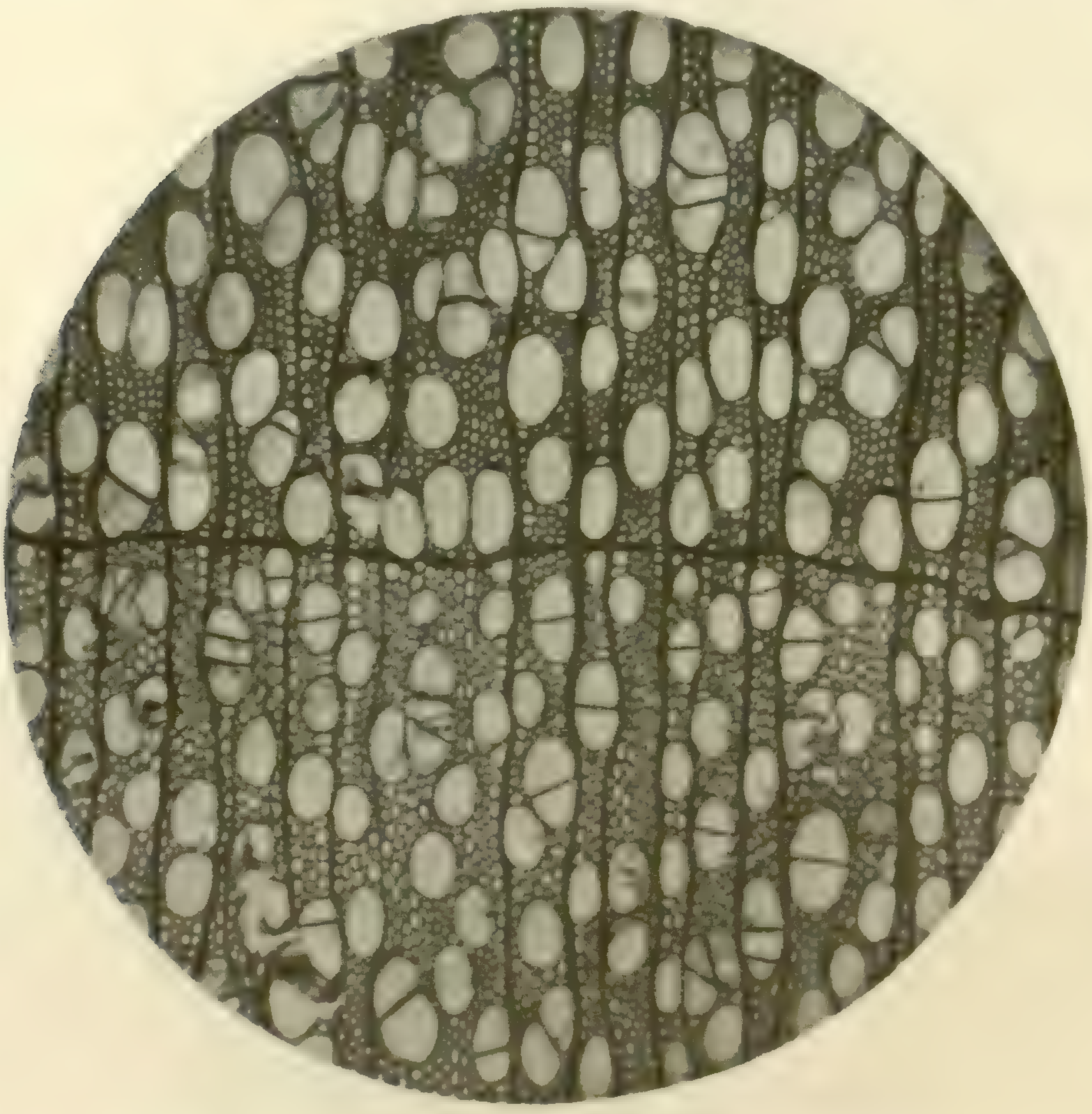

FIG. 6.—*Salix alba*. Transverse section showing characteristic structure of the genus. × 52.

drical elements with somewhat thick and pitted walls, and abrupt or transverse terminations. In the medullary sheath they are generally only a few times longer than broad, but within the region of the secondary xylem, and especially in the limiting zone of the growth ring, they become much longer and proportionately narrower. Such features, however, whether exhibited in transverse or longitudinal section, are of an altogether gen-

eralized type, and they possess no value for differential purposes. The wood parenchyma is always characterized by the presence of resinous matter which is generally deposited in large quantity, and it thereby gives a distinguishing feature to the elements which admits of their very ready recognition. This is especially true of them in the region of the medullary sheath, but it is also equally true in some other cases.

The distribution of the resinous wood parenchyma as dis-

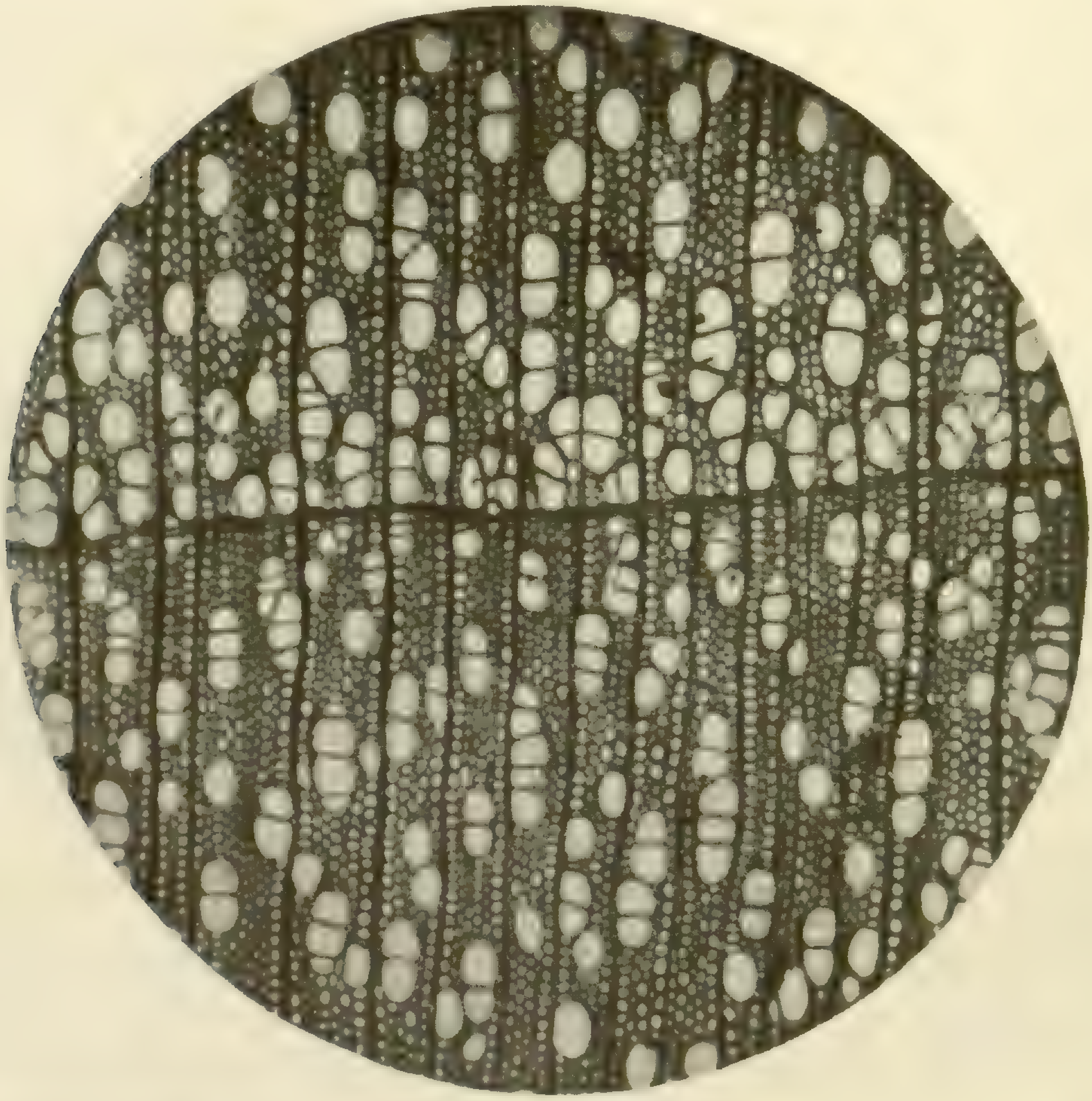

FIG. 7.—*Populus tremuloides.* Transverse section showing the characteristic structural features of the genus. × 52.

played in transverse section, presents features of special value for diagnostic purposes. In all of the Salicaceæ it forms a thin, limiting zone on the outer face of the growth ring. This zone varies somewhat in thickness and continuity, but as a rule it is composed of a continuous series of cells forming a layer from one to three elements thick (Figs. 6, 7). But in the

genus Salix, other features of importance for differential purposes are presented. Thus in *S. cordata* the cells occur in large numbers throughout the woody zone, and are distributed in such manner as to form rather conspicuous and often somewhat extensive tracts disposed without any reference to an orderly arrangement. In *S. sessilifolia* and *S. longifolia*, it not only occurs in the limiting zone, but it is also definitely associated with the

FIG. 8.—*Populus tremuloides.* Tangential section. × 52.

vessels as in *S. cordata*, forming about them a narrow but discontinuous layer, or as isolated cells at various parts of the periphery. All other species of Salix, so far as indicated by present investigations, have the wood parenchyma confined to the limiting zone of the growth ring, a rule which also seems to apply to Populus without exception.

The Vessels. — The chief diagnostic value of the vessels is to

be found in their distribution and compounding as exposed in transverse section, but before considering these features, it may be well to discuss the few details relating to their aspects in longitudinal section.

Thyloses are a general feature of the vessels in wood of the Salicaceæ, but they differ in some important essentials from those with which we are familiar in other woods, *e.g.*, Catalpa or Pinus. They generally fill the cavity of the vessel so completely (Figs. 6, 7) that in transverse section they seem to be entirely wanting. This is due to the fact that they undergo no longitudinal division, and as a result there is only one thylosis transversely, which is closely applied to the wall of the vessel. It will nevertheless be observed that in longitudinal section, instead of the modified spherical form usually assumed in woody stems, the thyloses of the Salicaceæ are really in the form of long, cylindrical cells several times longer than broad, but of very variable length. It is this last feature among others, which results in their apparent absence from the transverse section, since a given plane of section is most likely to pass between terminal walls, and as the thyloses lie in a single series, there are no longitudinal walls to break up the cavity of the vessel.

Apart from the well known structure which distinguishes all the vessels of the wood in angiosperms, it will be found that the radial walls are characterized by bordered pits which are chiefly somewhat distant, sometimes conspicuously so, and in consequence they are either oval or round (Fig. 10). It is rather the exception that they are so aggregated as to become hexagonal. On the other hand, in the tangential section, the pits are invariably crowded together to such an extent that they are typically hexagonal (Fig. 11), and the space between contiguous pits is represented by only a very narrow line of secondary wall joined directly to the primary wall. These differences will be found in exact accord with the distribution of the pits on the radial and tangential walls as described for the transition zone, and they seem to imply that the transverse movement of the transpiration current must be somewhat more energetic in a tangential than in a radial direction, contrary to what has been found to be the case in the Coniferales.

In transverse section the distribution, form, and compounding of the vessels impart to the structure an appearance quite similar to that found in the Rhamnaceæ. This very striking resemblance is likely to result in confusion unless very careful attention is given to details; and the likelihood of error from this source is all the more probable when it is observed that there is also a strong similarity of structural detail in radial section. It is, however, not our purpose to discuss these resem-

FIG. 9.—*Salix alba.* Tangential section. × 52.

blances at the present moment, since the essential differentiations of the two families will be sufficiently emphasized by their separate study. In the Salicaceæ the vessels give to the entire structure a high degree of porosity which is extended more or less uniformly to the entire thickness of the growth ring (Figs. 6, 7). This general law is subject to variation in detail. Thus

in such types as *Salix alba* (Fig. 6), *S. lævigata*, or *S. longifolia* they are so abundant as to give the impression of predominance, an impression which is greatly strengthened in *S. lasiandra* where the vessels justify the description of "strongly predominant throughout." The same law of distribution also applies to the poplars, though with the very essential difference that while in Salix there appears to be no very essential numerical reduction as between the initial zone and that which terminates the growth ring (Fig. 6), in Populus on the contrary, the initial zone usually shows a great increase in numbers with a more or less gradual diminution toward the termination of growth for the season (Fig. 7). This is fully expressed in such species as *P. alba*, *P. wislizeni*, *P. angustifolia*, etc., but in *P. monilifera* there seems to be a predominance which is fully maintained until the region of the summer wood, when there is an abrupt reduction.

The form of the vessel is typically oval in a radial direction (Fig. 7), but this is sometimes varied to oblong as in *Salix alba* (Fig. 6) or *S. lævigata*, or to broadly oval as in *Populus heterophylla*, or even to transversely oval as in *P. alba*. While in general, the vessels are largest in the initial growth of the season, the diminution in size toward the outer face of the growth ring may proceed gradually and without any very marked alteration as in *P. tremuloides* (Fig. 7); they may become abruptly smaller as in *P. fremonti*, or they may exhibit a graduated diminution as in *S. uva-ursi*.

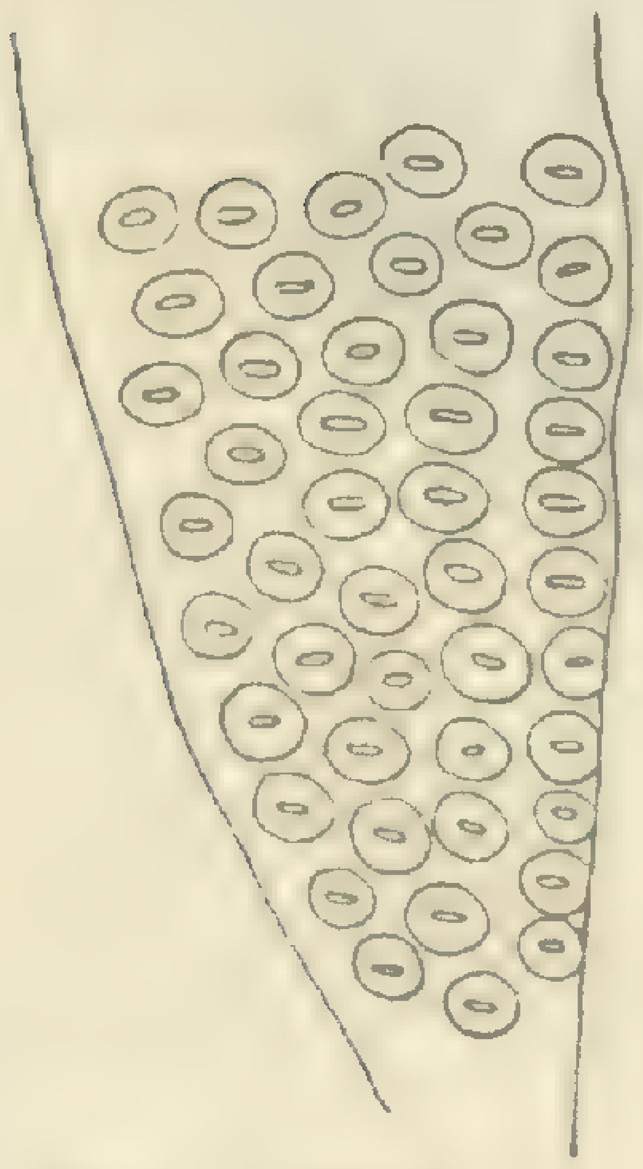

FIG. 10.—*Populus tremuloides*. Radial section showing the round or oval and distant bordered pits. × 350.

One of the most striking features of the vessels in the transverse section, is their peculiar compounding, a feature also similarly expressed in the Rhamnaceæ. Such compounding in the Salicaceæ always occurs in such manner as to give rise to radial series (Figs. 6, 7) and in the various forms of complexity thus arising, it constitutes within certain limits, a valuable differential character for the various species. Thus in *Salix longifolia*, *S. discolor*, *S. uva-ursi*, *Populus*

alba, *P. fremonti*, *P. pyramidalis*, *P. balsamifera*, etc., the large, oval vessels later become reduced in size, but they chiefly remain single or become sparingly 2-compounded. In *Salix alba* (Fig. 6), *S. sessilifolia*, or *S. brachystachys*, the vessels are chiefly 1-, 2-, or rarely 3-compounded; in *S. nigra*, they are rarely 8-compounded; in *S. lasiolepis* they are chiefly single throughout; in *S. lancifolia* they are rarely 4-compounded; in *Populus fremonti* they are rarely 5-compounded, and similar variations are to be met with throughout the entire family, always with the status of specific characters. While the general facts are thus noted, it will be sufficient to refer to the various diagnoses for an amplification of such details. It is only occasionally that the vessels assume a definitely resinous character. This is expressed among the species so far investigated, only by the unusually resinous *Salix cordata*, the vessels of which are everywhere resinous.

Medullary Rays.—As in the Coniferales so in the Salicaceæ, the medullary ray presents some of the most important of all the structural features for diagnostic purposes. Their value is of both a generic and a specific character. They are expressed in both radial and tangential sections which it will be desirable to discuss separately somewhat in detail.

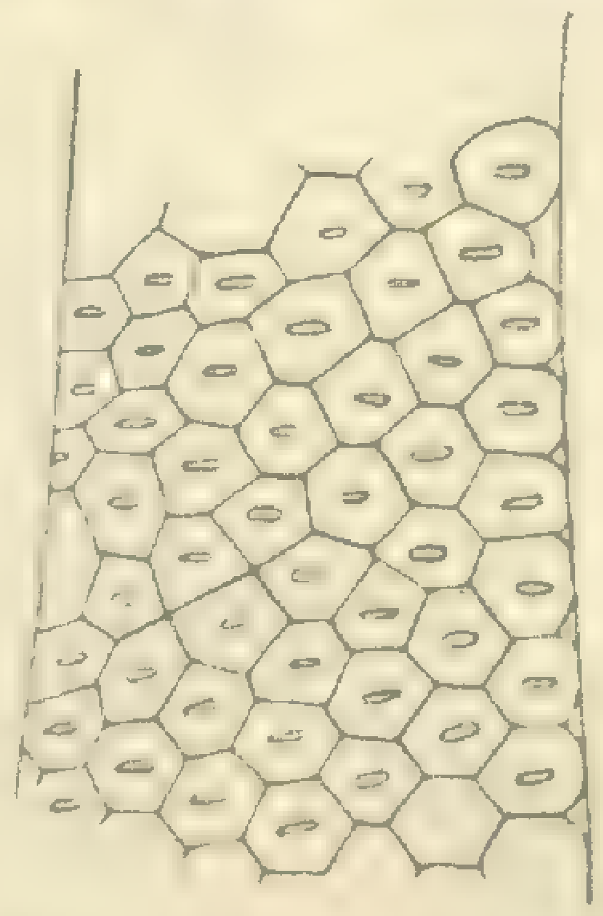

FIG. 11.—*Populus tremuloides*. Tangential section showing the multiseriate and hexagonal bordered pits. × 350.

In their tangential aspects the medullary rays of the Salicaceæ may be described as chiefly narrow; 1- or more rarely 2-seriate in part. From this there is no essential deviation which applies to one genus more than to the other, except in so far as variation is rather more characteristic of Salix, and constancy more characteristic of Populus. It may be said that broad rays, or rays with oval or transversely oval cells, and 2-seriate rays are more common to the former than to the latter. Such differences will be made sufficiently clear by a comparison of Figs. 12 and 14, and Figs. 12 and 15.

One of the chief factors in the tangential section of the ray, is the occurrence of ray cells of two kinds and the possibility of distinguishing them from one another. These cells will be

referred to as (1) and (2), and their more detailed characteristics will be discussed in connection with the radial section. In the genus Populus, as clearly shown in *P. tremuloides* (Figs. 12, 13), there is no clearly defined distinction between the two kinds of cells by means of which each may be recognized beyond question. In Fig. 13, the distinction is clear by reason of the distribution of the resin and the special location of each kind of cell. Thus the more resinous cells, *a*, occupying the central region, are of the first order (1), while the less resinous cells, *b*, occupying the extremities of the ray, are of the second order (2). This differentiation serves to illustrate the general law that the cells of the first order are usually the more strongly resinous, and that the less resinous cells of the second order are chiefly terminal unless also interspersed. But such distinctions are not always valid, even in the same species, since in Fig. 12, taken from the same section, the non-resinous terminal and interspersed cells, *b*, are probably all of the second order, while the more resinous cells, *a*, are chiefly of the first order. But the three resinous and terminal cells of this figure involve considerable doubt as to their precise character, inasmuch as their positions would lead us to assume that they must be of the second order in spite of their resinous contents, a view which gains force from what may sometimes be observed in radial section.

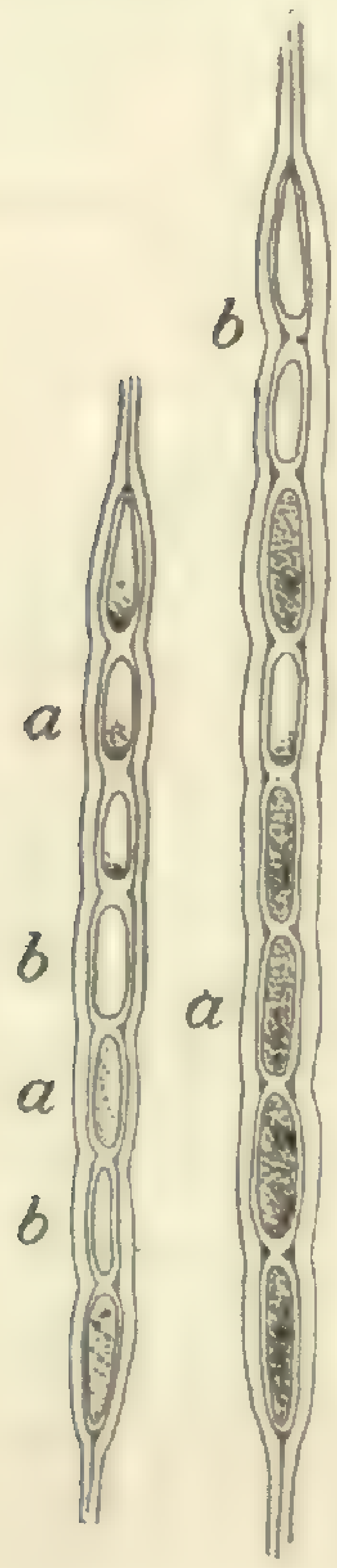

FIG. 12. — *Populus tremuloides*. Tangential section of the narrow medullary rays. *a*, cells of the first order; *b*, usually non-resinous cells of the second order. × 350.

FIG. 13. — *Populus tremuloides*.—Tangential section of a medullary ray with broader and resinous cells of the first order, *a*, clearly distinguishable from the non-resinous and somewhat narrower cells, *b*, of the second order. × 350.

In the genus Salix (Figs. 14 and 15), where the structure is of a more decidedly resinous character, the cells of the medullary rays are usually all resinous, and this feature serves no useful purpose in differentiations. We do find, nevertheless,

that in position and form, as also usually in size, there are differential features of well defined value. Thus in *Salix longifolia* (Fig. 14) there is no room for hesitation between the round or transversely oval cells, *a*, of the first order constituting the bulk of the structure, and the oblong narrow and terminal cells, *b*, of the second order. Or again in the same species (Fig. 15), the same difference appears in the 2-seriate form of the ray. In low rays, the tendency is for the cells of the first order to be replaced by those of the second order as also shown in Fig. 15 on the right. From these considerations it will be obvious that the distinctness with which these two forms of cells appear in the tangential section is of importance as a basis of generic differentiation.

FIG. 14.—*Salix longifolia*. Tangential section of a medullary ray showing the resinous character of the cells; the round or chiefly transversely oval form of the cells of the first order, *a*, and the larger and narrower cells, *b*, of the second order, the two forms of cells being sharply differentiated. × 350.

A second factor of value is to be found in the form of the ray cell and its variations. In the genus Populus, the cells of two kinds present little or no difference in form by which they may be distinguished from one another. This is especially true of *P. balsamifera*, *P. heterophylla*, *P. monilifera*, etc., while in *P. tremuloides* (Fig. 13), *P. alba*, *P. pyramidalis*, *P. grandidentata*, etc., there is a somewhat obvious difference in many cases which, taken in conjunction with other features, serves to bring such species into a separate group. Thus

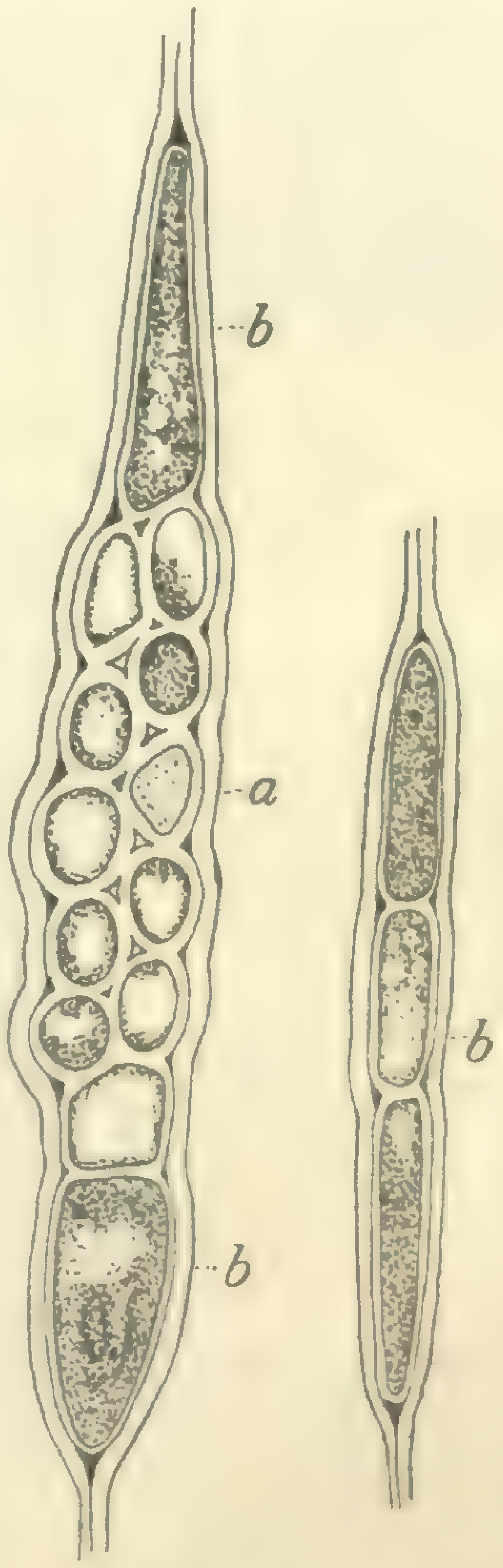

FIG. 15. — *Salix longifolia*. Tangential section of two rays, the one showing the 2-seriate form embracing cells of the first order, *a*, together with larger terminal cells, *b*, of the second order, the two clearly differentiated: the other showing a low ray entirely composed of cells, *b*, of the second order. × 350.

it will be found that where such differences exist, the cells of the second order are generally narrower and relatively or absolutely longer. The cells of the first order are, as a rule, chiefly narrow and oblong. Few exceptions to this occur (Fig. 15) though they may appear not only in the same species but also in the same section. On the whole it may be said that Populus is generally characterized by narrow and oblong cells — the tendency to an oval or round form being of the nature of an exception. In the genus Salix, on the contrary, the typical form of the cell (1) is oval, round or even transversely oval (Figs. 14, 15), the occurrence of narrow and oblong cells being of the nature of an excep-

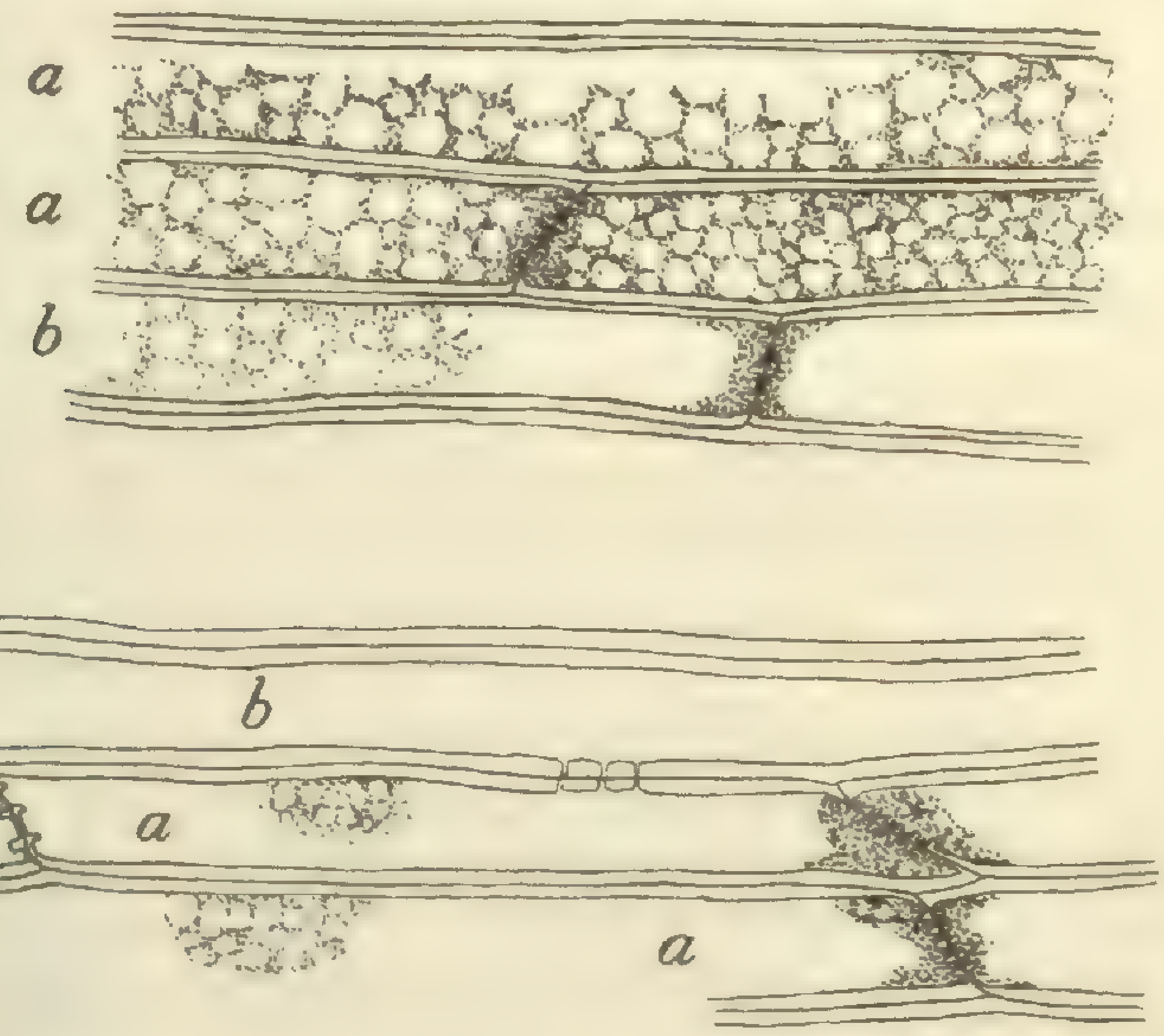

FIG. 16.—*Populus tremuloides.* Radial section of medullary rays showing the often resinous character and structural details in cells of the first order, *a*, and the second order, *b*. × 350.

tion. The cells of the second order (2) are also much longer and narrower than in Populus, differences which will be readily explained by the radial sections, so that considering these differences as a whole, they again afford a valuable element in generic differentiations.

The radial aspect of the medullary ray is, in many respects, the most important for diagnostic purposes inasmuch as it exhibits very striking differences of structure and form which are not only of generic but of specific value. These differences are expressed most prominently in the form and character of the cells whereby it is necessary to recognize cells of two kinds. Fundamentally the ray is composed of cylindrical cells several

times longer than broad, and either of uniform width throughout or somewhat contracted at the ends. The terminal walls are always more or less strongly pitted, but they exhibit somewhat striking variations in this respect as between Salix (Fig. 17, *a*) and Populus (Fig. 16, *a*). The upper and lower walls are rather thick and often strongly pitted, but in both of these respects there is a marked difference between the two genera in such a way that in Populus (Fig. 16, *a*) there is always a tendency to a relatively thin wall with few pits, while in Salix (Fig. 17, *a*) the tendency is always toward a very thick and strongly pitted wall. Such cells are generally resinous, more strongly so in Salix than in Populus, and it is in them that resin is found when it may

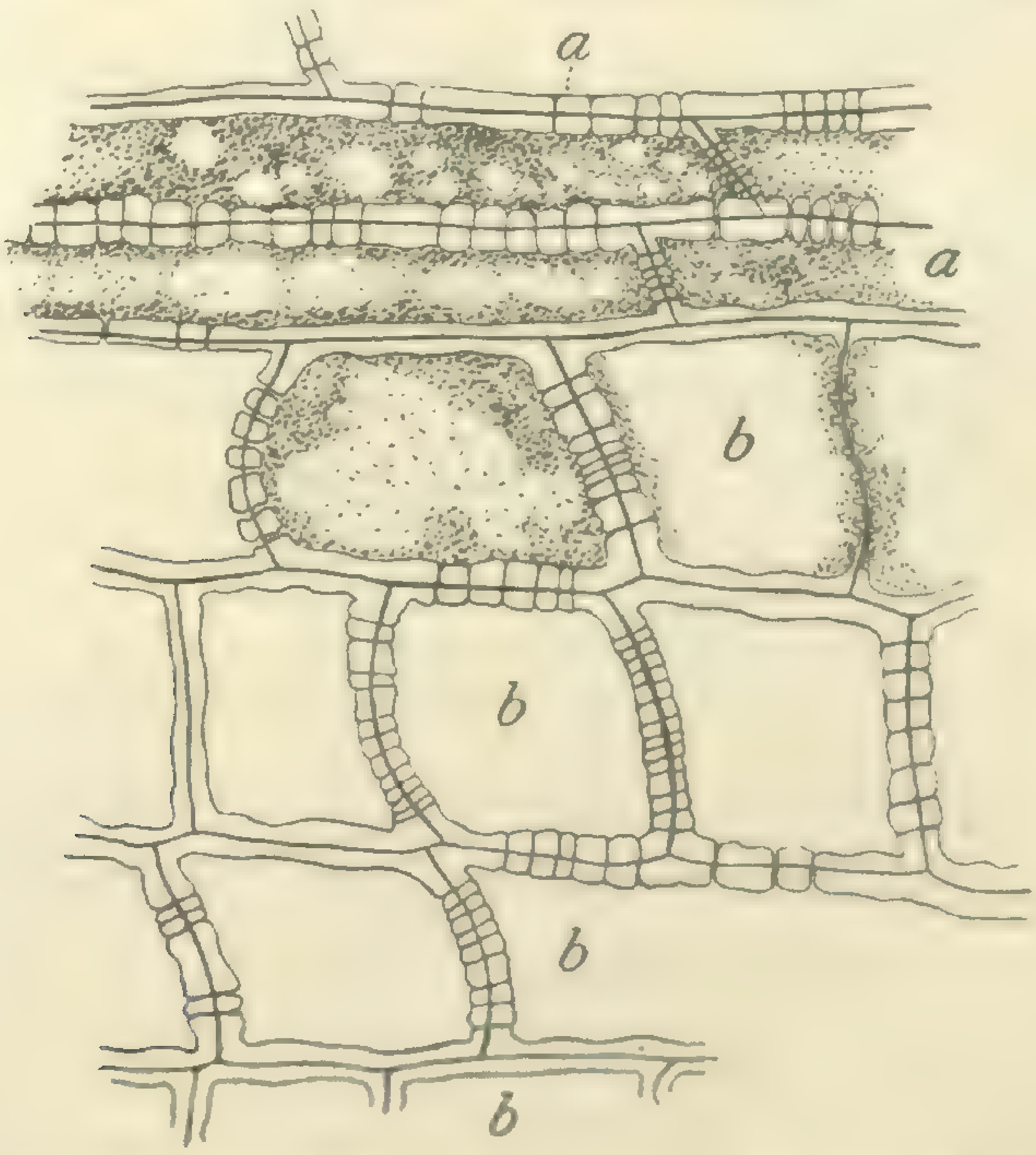

FIG. 17.—*Salix hookeriana*. Radial section of a medullary ray showing details in the structure of the cell walls: cells *a* of the first order, and cells *b* of the second order, the latter occupying a marginal position. × 350.

have been eliminated from all other parts of the ray. Such cells I have designated as "cells of the first order" or (1). They seem to be the more primitive parts of the structure, and in this sense they are comparable with the parenchyma cells of the gymnosperms (Penhallow, :04c). Their radial walls are generally devoid of pits except that in a few instances I have observed the occurrence of minute and simple pits opposite wood cells, but so far as can be ascertained at the present time, this feature possesses no special significance.

Together with the cells of the first order, cells of a somewhat and often wholly different character appear. In the genus Populus, this differentiation is expressed with the least force, and it is difficult or even impossible to distinguish between the two except through certain special structural features of the radial walls. Such cells are, generally speaking the least resinous. To all such I have applied the designation "cells of the second order" or (2). An inspection of Fig. 16 taken from *Populus tremuloides*, will show that there is essentially no distinction as to form and structure, between cells of the first order, *a*, and those of the second order, *b*, and it is only when we study such cells opposite vessels that the distinction becomes obvious. In such regions cells (2) invariably show either oval (Fig. 18) or quadrangular pits (Fig. 19) disposed in somewhat definite radial series. Such pits and of the forms described, are characteristic of the genus Populus, and from this there is no essential deviation so far as our investigations have proceeded. These features make it clear why the tangential section of a ray in Populus does not give a clear differentiation of the two kinds of cells. In the genus Salix the case is very different. There we always find the ray characterized by the presence of cells which are very much shorter and very much higher, so that they become isodiametric (Fig. 17, *b*). But it also very often happens that the alteration thus indicated is subject to extreme exaggeration in such a way that the cells become several times higher than long, and therefore *high and narrow.* This is a feature peculiar to Salix, and it has not been observed in any form in Populus. It is this very strong difference in form, as well as the very striking variations in size among the cells of the second order, which serves to establish so strong a differentiation between the two kinds of cells as exposed in tan-

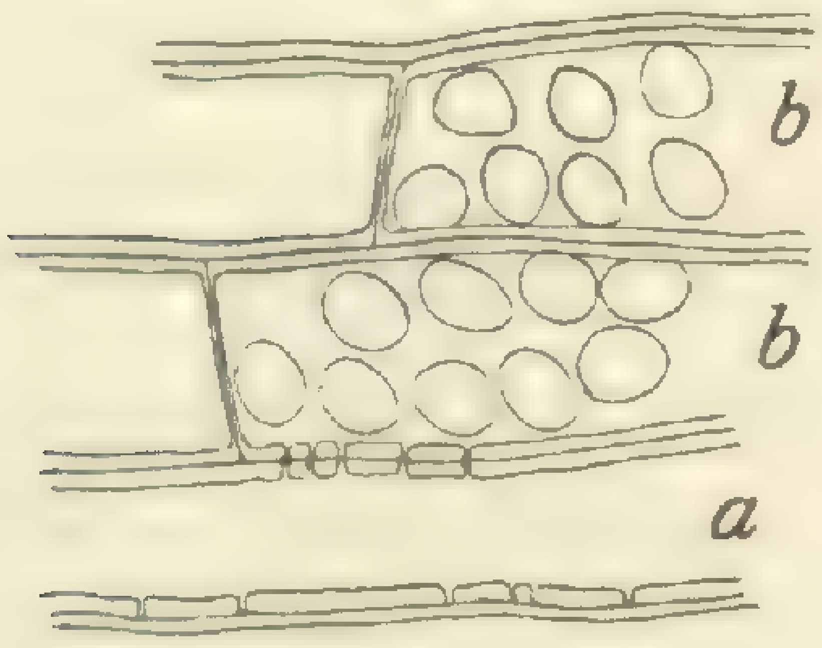

FIG. 18. — *Populus tremuloides.* Radial section of cells of the second order (2) showing oval pits on the lateral walls opposite vessels. × 350.

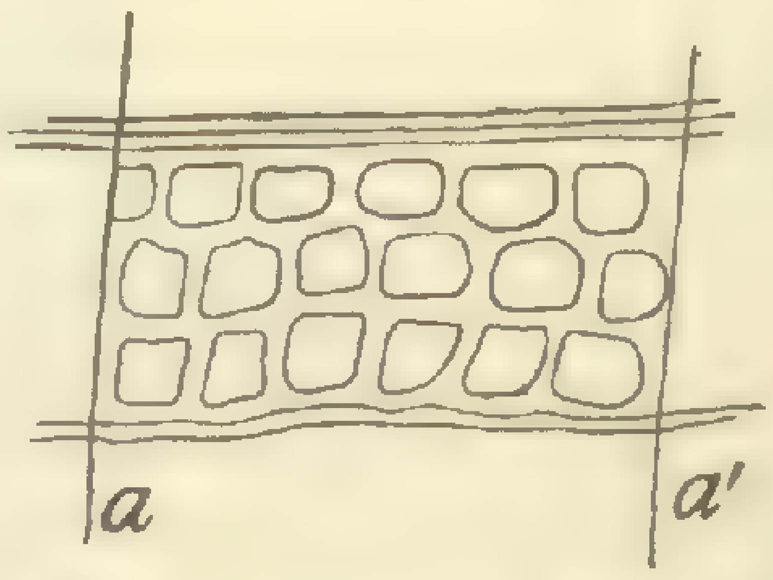

FIG. 19. — *Populus tremuloides.* Radial section of cells of the second order, (2) showing quadrangular pits on the lateral walls opposite vessels. × 350.

gential section. In addition, however, the cells (2) are always characterized by their peculiar pits on the radial walls when opposite vessels. These pits are very rarely of the oval or quadrangular form presented by Populus. On the other hand they are more or less definitely angled and crowded as typically presented by *Salix alba* (Fig. 20.) But such a form is subject to very marked and significant variation. Thus in such types as *S. sessilifolia*, the individual pits vary very greatly in size and form, sometimes being greatly reduced in size and multiplied in number, or again they diminish in number and increase greatly in size (Fig. 21); and not infrequently — indeed we might say that very often, even in the same species — there are all degrees of transition exhibited from the angled pit of *Salix alba* (Fig. 20) to typical scalariform structure in *S. sessilifolia* (Fig. 22). Such transitional forms are peculiar to Salix.

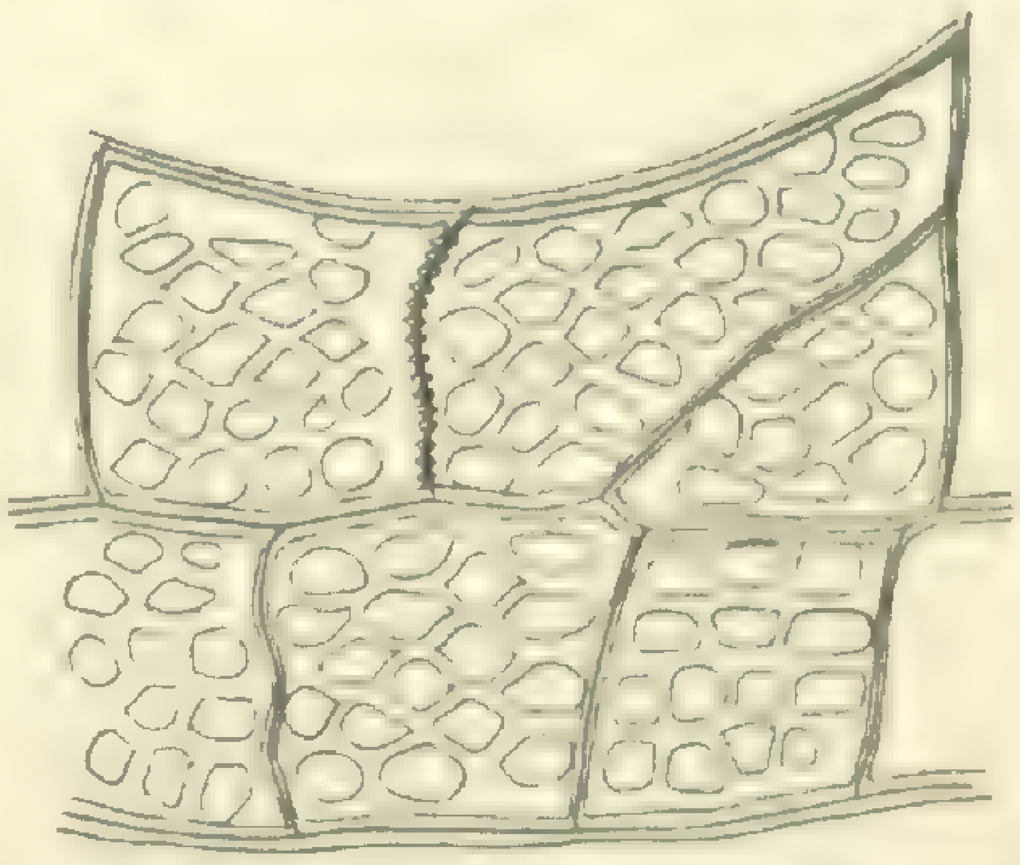

FIG. 20 — *Salix alba*. Radial section of cells of the second order (2), showing their form and the character of the angled pits on the lateral walls opposite vessels. × 350.

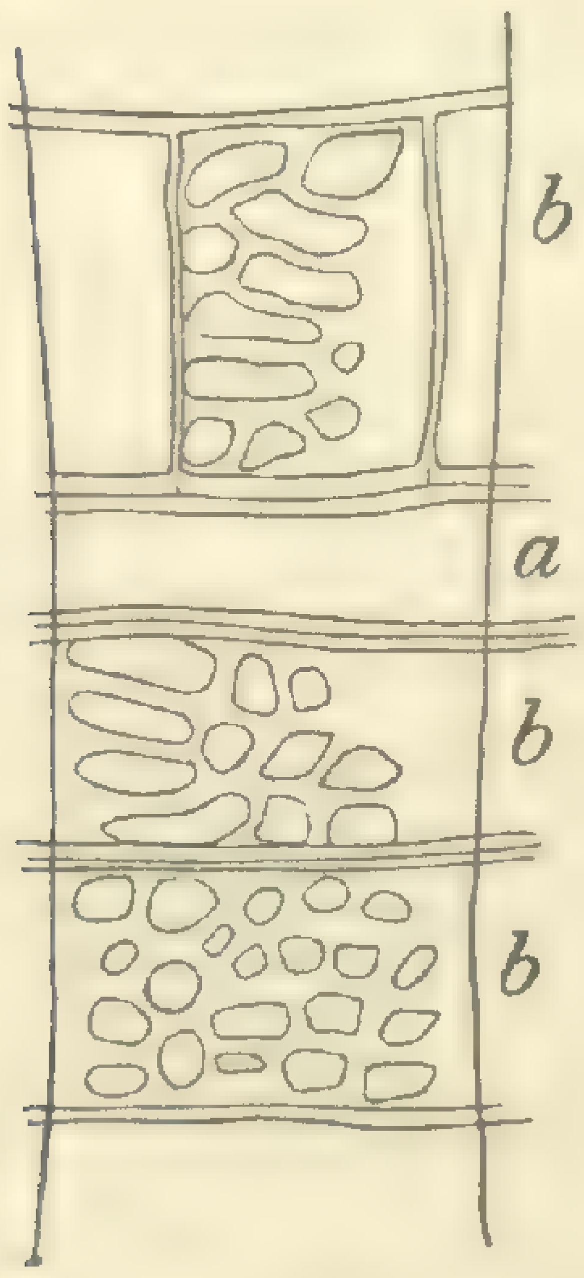

FIG. 21. — *Salix sessilifolia*. Radial section showing a cell, *a*, of the first order (1), and cells, *b*, of the second order (2) with variable, angled pits on the lateral walls opposite vessels, merging into scalariform structure. × 350.

In the genus Populus the distribution of the two kinds of cells is effected in such a way that those of the first order occupy the central region, while those of the second order occupy the margins above and below (Fig. 16, *b*, *b*; Fig. 13, *b*, *b*). Occasionally there is an interspersal with the cells of the first order (Fig. 12, *b*, *b*), but in such cases, as already pointed out, it is not always easy to distinguish the two kinds of cells, especially in a tangential section. In the genus Salix the same relation exists (Fig. 21, *a*), with the difference that interspersal is a much more common feature, and the distinction of the two kinds of cells may be made without any difficulty in any plane of section. The relations thus indicated show that there is a tendency toward replace-

ment of the more primitive cells (1) by those (2) of a more advanced and specialized functional value; and this tendency is carried to such an extent that in low rays the replacement is often complete (Fig. 15). It is of interest from a developmental point of view to note that this relation is precisely that which has already been shown to exist among the higher gymnosperms, with respect to the relative preponderance of parenchyma cells and ray tracheids, and such a comparison goes far to prove, especially in connection with other relations to be described immediately, that the cells of the second order are of the higher type of development.

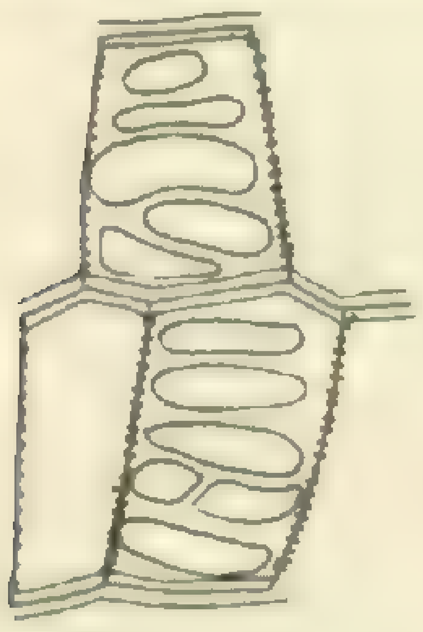

FIG. 22.—*Salix sessilifolia.* Radial section of a cell of the second order (2) showing complete transformation into scalariform structure opposite a vessel. × 350.

The features thus described for the radial section of the medullary ray, are of both generic and specific value as will be seen from the diagnoses given, but it should be pointed out that the recognition of two forms of cells in the medullary ray of the Salicaceæ is exactly parallel with what has already been noted as characteristic of the Coniferales (Penhallow, :04c), though with one important difference. In the gymnosperms the ray contains in its more primitive condition, parenchyma cells only, although these later become differentiated into two specialized forms. As a whole, these are equivalent, from the standpoint of development and functional value, to cells of the first order in the Salicaceæ. But in all the higher Coniferales the ray also contains specialized ray tracheids which manifestly provide greater freedom in radial circulation, and as already shown elsewhere, (Penhallow, :04c), such development is in direct response to the requirements of a higher type of organization. No such tracheids occur in the rays of the Salicaceæ, but they are exactly represented in a functional sense by the cells of the second order (2), which also serve as evidence of a higher type of organization.

While it is not our present intention to discuss the phylogeny of the Salicaceæ in detail, and to establish its relative position in the scale of evolution, it is desirable to indicate that the general trend of the evidence so far collected — geographical,

geological, anatomical—is all in one direction, and that is to show that the genus Populus is essentially the more primitive member of the family, and that it is the genus through which we must probably seek connection with ancestral forms.

It only remains to point out that with respect to a delimitation of species and varieties, the rule adopted for the gymnosperms (Penhallow, :04c) applies with equal force here, to the effect that varieties have no proper status on anatomical grounds, and what are designated as such on the basis of external morphology must be regarded as species from the standpoint of the present studies.

SALICACEÆ.

Transverse.— Growth rings usually devoid of recognizable differentiation of spring and summer wood, the outer limits being defined by a usually resinous wood parenchyma of radially narrower cells, forming a zone upwards of three elements thick. Wood cells variable, hexagonal, and usually not in obvious radial rows. Vessels numerous throughout, often predominant, and more or less radially compounded.

Radial.— Medullary rays composed of two kinds of cells, *i. e.*, those without (1) and those with (2) pits on the lateral walls opposite vessels. Vessels commonly with thyloses, their radial walls with numerous, multiseriate, usually localized, oval, round, or hexagonal bordered pits.

Tangential.— Medullary rays chiefly narrow: 1- or more rarely 2-seriate in part. Vessels with numerous, multiseriate, hexagonal, bordered pits throughout.

1. Populus.

Radial.— Ray cells of two kinds but presenting no essential distinction as to length, height, and thickness of the walls: the pits on the lateral walls of cells (2) more definitely rounded, oval or sparingly angled, when they become quadrangular and lie in radial series, never merging into scalariform structure.

Tangential.— The two kinds of ray cells not clearly distinguishable.

Synopsis of Species.

Ray cells (2) (tangential) more or less distinguishable by differences in height, breadth, and less resinous contents.

Rays (tangential) 2-seriate in part.

Ray cells (1) somewhat variable, oblong, narrow, or broader and oval; unequal.

Vessels (transverse) broad, oval, 1- to 3-, more rarely 5-compounded. 1. *P. fremonti.*

Rays (tangential) strictly 1-seriate.

Ray cells (1) (tangential) uniform, narrow, oblong, equal, but occasional rays with broader, oval, and somewhat variable, unequal cells.

Vessels (transverse) broad, oval, or transversely oval, 1- to 2- or rarely 4-compounded. . . . . . . 3. *P. alba.*

Vessels (transverse) broadly oval, 1- to 4- or rarely 7-compounded. 4. *P. tremuloides.*

Ray cells (1) (tangential) uniform, narrowly oblong, and equal, but in different rays sometimes broadly oblong.

Vessels (transverse) very numerous, broad, 1- to 3- or rarely 4-compounded. . . . . 5. *P. pyramidalis.*

Vessels (transverse) numerous, much smaller toward the outer face of the growth ring, 1- to 4- or rarely 5-compounded. 6. *P. grandidentata.*

Ray cells (2) (tangential) not distinguishable from (1).

Rays (tangential) all strictly 1-seriate.

Rays (tangential) with diminishing terminal width.

Vessels (transverse) at first predominant, gradually diminishing in size and number, 1- to 3-, rarely 4- to 5-compounded. 7. *P. wislizeni.*

Rays (tangential) of uniform width throughout.

Vessels (transverse) numerous, oval, 1- to 4- or rarely 5-compounded. . . . . 8. *P. balsamifera.*

Vessels (transverse) at first predominant, gradually diminishing in size and number; 1- to 4-, rarely 6-compounded. 9. *P. angustifolia.*

Vessels (transverse) numerous throughout, abruptly smaller in the outer portions of the growth ring; 1- to 4-compounded. 10. *P. trichocarpa.*

Vessels (transverse) numerous, large, oval, or round, often in series continuous and compounded with those of the previous season: chiefly single but often 2-, and on the outer face of the growth ring sometimes 3-compounded. . . 11. *P. heterophylla.*

Rays (tangential) 2-seriate in part.

Rays (tangential) uniform in width throughout.

Vessels numerous throughout, broadly oval, abruptly fewer in the region of the summer wood, chiefly single, or less frequently 2- to 3-compounded. . . . . 2. *P. monilifera.*

1. *P. fremonti* Wats.

Transverse.— Growth rings very broad, the limiting zone of wood parenchyma devoid of resin, 1 to 2 cells thick. Vessels large, broad, oval, becoming somewhat abruptly smaller toward the outer limits of the growth ring; 1- to 3-, more rarely 5-compounded. Rays numerous, sparingly resinous, one cell wide, distant upwards of 12 rows of wood cells.

Radial.— Ray cells (1), the upper and lower walls thin and finely pitted; the terminal walls straight or curved and finely pitted. Cells (2), the upper and lower and terminal walls thin, very finely and obscurely pitted; the pits on the lateral walls forming a coarse, sieve-plate structure.

Tangential.— Rays medium to high, numerous, 1-seriate, very sparingly resinous, sometimes 2-seriate. The cells (1) somewhat variable, oblong and narrow or broader and oval, unequal. Cells (2) not conspicuously different but the terminal ones sometimes higher, the interspersed ones sometimes narrow.

2. *P. monilifera* Ait.

Transverse.— Growth rings medium to narrow, the limiting wood parenchyma devoid of resin, in 2 to 3 rows. Vessels numerous throughout, broadly oval, becoming rather abruptly fewer at the outer limits of the ring, chiefly single, or less frequently 2- to 3-compounded. Medullary rays prominent, numerous, very sparingly resinous, and distant upwards of 6 rows of wood cells, one cell wide.

Radial.— Rays sparingly resinous, the cells contracted at the ends. Cells (1), the upper and lower walls rather thick, unequal, and finely pitted; the terminal walls thick, straight or curved, and finely pitted. Cells (2), the upper and lower walls thick and finely though remotely pitted; the terminal walls often strongly curved, thick, and finely pitted; the pits on the lateral walls round, oval, or sparingly angled, in radial series.

Tangential.— Medullary rays very numerous, low to high, very sparingly resinous, 1-seriate or sometimes 2-seriate in part. Cells (1), uniform in the same ray and oblong, equal but in different rays ranging from very narrowly oblong to rather broadly oblong. Cells (2) not distinguishable.

3. *P. alba* (Linn.).

Transverse. — Growth rings narrow, uniform, the limiting wood parenchyma very sparingly if at all resinous, in 1, sometimes 2 rows. Medullary rays prominent, somewhat resinous, 1 cell wide, distant upwards of 8 or sometimes 10 rows of cells. Vessels broad, oval, or transversely oval, at first predominant, gradually diminishing in size and number outwardly; 1- to 2-, or more rarely 4-compounded.

Radial. — Medullary rays very sparingly resinous. Cells (1), the upper and lower walls rather thick, finely but strongly pitted: the terminal walls straight, often diagonal, finely pitted: equal to about 6 wood cells, straight. Cells (2), the upper and lower walls somewhat thinner and not obviously pitted; the terminal walls conspicuously though finely pitted: the pits on the lateral walls hexagonal, forming a coarse, sieve-plate structure; somewhat variable in height and sometimes rather short.

Tangential. — Rays numerous, very sparingly resinous, medium, 1-seriate. Cells (1) chiefly uniform, narrow, oblong, and equal, but occasionally rays with broader, oval, and somewhat variable and unequal cells. Cells (2), uniform, narrow, somewhat variable, the terminal ones often much higher.

4. *P. tremuloides* Michx.

Transverse. — Growth rings broad, uniform; the limiting wood parenchyma sparingly resinous, in 1 to 2 rows. Vessels at first medium, becoming larger and finally smaller toward the outer limits of the growth ring, broadly oval, 1- to 4- or more rarely 7-compounded. Medullary rays rather numerous, one cell wide, sparingly resinous, distant upwards of 10 rows of wood cells.

Radial. — Ray cells sparingly resinous, straight. Cells (1), the upper and lower walls thin, and finely pitted; the terminal walls thin, straight or curved, and rarely pitted. Cells (2), the upper and lower walls thin and sparingly pitted; the terminal walls rarely pitted, often curved; the pits on the lateral walls round, chiefly in radial series.

Tangential. — Rays numerous, resinous, low to high, 1-seriate. The cells (1), uniform, narrowly oblong and equal, low rays sometimes showing broader and oval cells throughout. Cells (2) not readily distinguishable, but in low rays sometimes twice as high and less resinous.

5. *P. pyramidalis* Ait.

Transverse. — Growth rings rather broad, uniform; the limiting wood parenchyma in 1 to 2 rows, sparingly resinous. Vessels very numerous, broad, becoming gradually smaller toward the outer limits of the growth ring: 1- to 3-, more rarely 4-compounded. Medullary rays prominent, narrow, one cell wide, numerous, and distant upwards of 7, more rarely 10 rows of cells; somewhat resinous.

Radial. — Medullary rays sparingly resinous; the cells straight, becoming much shorter in the region of the summer wood. Cells (1), the upper and lower walls thin and strongly pitted throughout; the terminal walls finely pitted. Cells (2), the upper and lower walls thin and sparingly pitted: the terminal walls finely pitted: the pits on the lateral walls round or sparingly angled.

Tangential. — Rays very numerous, resinous, medium to high, narrow, 1-seriate. The cells (1) chiefly uniform, rather narrowly oblong and equal in the same ray, but in different rays sometimes varying to broadly oblong. Cells (2) not readily distinguishable except by their less resinous contents and somewhat more variable form and unequal size, usually giving the ray a diminishing terminal width.

6. *P. grandidentata* Michx.

Transverse. — Growth rings narrow, uniform; the limiting wood parenchyma with thin-walled cells in 1 to 3 rows, often very resinous. Vessels numerous throughout the growth ring but usually much smaller near the outer limits of the ring; 1- to 4-, more rarely 5-compounded. Medullary rays prominent but narrow, 1 cell wide and distant upwards of 10 or sometimes 12 rows of cells; somewhat resinous.

Radial. — Ray cells straight. Cells (1), the upper and lower walls thin and entire or obscurely pitted; the terminal walls thin, straight, or curved, finely pitted. Cells (2), the upper and lower walls rather thin and not obviously pitted; the terminal walls often strongly curved, rather thick, and conspicuously pitted; the pits on the lateral walls oval or round in radial series. Isodiametric, thin-walled idioblasts, containing each a single crystal of calcium oxalate of the quadratic system, often form extensive, longitudinal series adjacent to vessels.

Tangential. — Medullary rays numerous, narrow and high, strictly 1-seriate, resinous. The cells (1) chiefly uniform in the same ray and narrowly oblong, equal; but between different rays varying to oblong. Cells (2) not very readily distinguishable, but usually less resinous and often variable from narrowly oblong to oval so as to give the same ray a conspicuously unequal width.

7. *P. wislizeni* Watson.

Transverse. — Growth rings broad: the limiting wood parenchyma sparingly resinous in 1 to 3 rows. Vessels at first predominant, gradually diminishing in size and number toward the outer limits of the growth ring: 1- to 3-, more rarely 4- to 5-compounded. Medullary rays prominent, narrow, one cell wide, distant upwards of 10 rows of cells, numerous, sparingly resinous.

Radial. — Ray cells straight, equal to about 14 wood cells but becoming very short toward the outer limits of the growth ring. Cells (1), the upper and lower and terminal walls rather thin, rather obscurely and finely pitted; the pits on all the walls becoming much more prominent in the outer region of the growth ring. Cells (2), the upper, lower, and terminal walls not very different from (1); the pits on the lateral walls forming a coarse sieve-plate structure.

Tangential. — Rays numerous, narrow, medium to high, sparingly resinous, 1-seriate. Cells (1) uniform, narrowly oblong, and equal, sometimes becoming broader and oval in the central tract so as to form tapering extremities to the ray. Cells (2) not readily distinguishable but uniform, narrow, oblong, and equal.

8. *P. balsamifera* Linn.

Transverse. — Growth rings medium, uniform; the limiting wood parenchyma conspicuously resinous, of one or sometimes two rows of cells. Vessels numerous, oval, becoming gradually smaller toward the outer limits of the growth ring; 1- to 4- or more rarely 5-compounded. Medullary rays numerous, prominent, resinous, one cell wide, and distant upwards of 8 rows of cells.

Radial. — Rays strongly resinous, the cells straight. Cells (1), the upper and lower walls thin and finely pitted: the terminal walls straight or curved, obscurely if at all pitted. Cells (2), the upper, lower, and terminal walls thin and obscurely if at all pitted; the pits on the lateral walls round, in radial series.

Tangential. — Rays very numerous, strongly resinous, low to high, 1-seriate. Cells (1) uniform in the same ray and oblong, but varying between different rays from narrowly oblong to broadly oblong, equal. Cells (2) not distinguishable except by their less resinous contents.

9. *P. angustifolia* James.

Transverse.— Growth rings broad; the limiting wood parenchyma conspicuously resinous, usually upwards of 3 rows of cells thick. Vessels at first somewhat predominant, gradually diminishing in number and finally in size toward the outer limits of the growth ring where they are very much reduced in size; 1- to 4-, rarely 6-compounded. Medullary rays numerous, prominent, resinous, 1 cell wide, distant upwards of 9 rows of cells.

Radial.— Ray cells straight. Cells (1), the upper and lower walls unequally rather thick and strongly pitted; the terminal walls rather thick and strongly pitted. Cells (2), the upper and lower walls sparingly pitted; the terminal walls thin and sparingly if at all pitted; the pits on the lateral walls round or oval and radially seriate.

Tangential.— Medullary rays numerous and very variable, low to high, narrow, resinous, 1-seriate. Cells (1) uniform in the same ray and chiefly very narrowly oblong, equal, but in some rays becoming twice as broad and oblong. Cells (2) not distinguishable.

10. *P. trichocarpa* Torr. & Gr.

Transverse.— Growth rings very broad: the limiting wood parenchyma sparingly resinous. Vessels numerous throughout, becoming abruptly

smaller in the outer limits of the growth ring; 1- to 4-compounded. Medullary rays narrow but rather prominent and somewhat resinous; one cell wide, numerous and distant upwards of 12 rows of cells.

Radial.— Ray cells straight. Cells (1), the upper and lower walls thin and not obviously pitted except in the outer limits of the growth ring; the terminal walls straight or curved, and finely pitted. Cells (2), the upper and lower walls usually thick and more or less strongly pitted; the terminal walls rather thick and strongly pitted; the lateral walls with round or sparingly angled and radially seriate pits.

Tangential.— Rays rather numerous, resinous, high, narrow, strictly 1-seriate. Cells (1) chiefly uniform, narrowly oblong and equal, in a few rays becoming broader and oblong, somewhat unequal. Cells (2) not readily distinguishable.

11. *P. heterophylla* Linn.

Transverse.— Growth rings medium, rather uniform; the limiting wood parenchyma not very prominent, usually one cell thick and often forming a discontinuous zone. Vessels numerous and large, oval or round, often in series continuous and compounded with those of the previous year, diminishing steadily in size toward the outer face of the growth ring: chiefly single but often 2-, or on the outer face of the growth ring sometimes 3-compounded. Medullary rays not very prominent, 1 cell wide, rather numerous and distant upwards of 6 or more rarely 10 rows of cells.

Radial.— Medullary rays non-resinous. Cells (1), the upper and lower walls, as also the terminal walls, usually rather thick and strongly pitted. Cells (2), the upper and lower walls somewhat thinner, less strongly pitted: the terminal walls strongly pitted; the lateral walls with round, oval, or sparingly angled pits.

Tangential.— Medullary rays numerous, rather high, non-resinous, narrow, 1 cell wide. Cells (1) chiefly uniform in the same ray, oblong and equal, but between different rays varying from narrowly oblong to rather broadly oblong. Cells (2) not distinguishable from the first.

2. Salix.

Radial.— Ray cells (1) usually low and thick-walled, several times longer than high; the upper and lower and terminal walls commonly pitted. Cells (2) often thin-walled, marginal, and interspersed, commonly predominant, very variable, short, and often several times higher than long; the pits on the lateral walls more definitely angled, forming more extensive and finer sieve-plates, and sometimes merging into definite scalariform structure.

Tangential.— Ray cells clearly distinguishable as of two kinds.

SYNOPSIS OF SPECIES.

Pits on the lateral walls of the ray cells (2) angled or oval and merging into an open, scalariform structure.

Resinous wood parenchyma prominent throughout in association with the vessels.

Rays (tangential) narrow, the cells (1) uniform, narrow and oblong.

Vessels oval, 1- to 2- or more rarely 3-compounded. 13. *S. sessilifolia.*

Resinous wood parenchyma confined to the outer limits of the growth ring.

Rays (tangential) numerous, resinous, and chiefly narrow. Cells (1) somewhat variable, chiefly oblong and narrow, more rarely oval, more or less conspicuously unequal.

Vessels broad (transverse), oval, 1- to 4- or finally 4- to 5-compounded. . . . . . . 14. *S. amygdaloides.*

Rays (tangential) resinous, numerous, broader; cells (1) variable, oblong to broadly oval and conspicuously unequal.

Vessels (transverse) predominant throughout, oval, 2- to 4- or finally 5-compounded. . . . . . . 15. *S. discolor.*

Rays (tangential) broad, more or less 2-seriate; the cells (1) variable, oval to oblong and conspicuously unequal.

Vessels (transverse) chiefly single throughout, but sparingly 2- to 3-compounded. . . . . . . 12. *S. lasiolepis.*

Pits on the lateral walls of the ray cells (2) hexagonal or quadrangular, forming coarse sieve-plates, but devoid of scalariform structure.

Resinous wood parenchyma conspicuous throughout the growth ring.

Resinous wood parenchyma confined to the vessels and the limiting zone.

Rays (tangential) numerous, resinous, 2-seriate in part; the cells (1) variable, narrowly to broadly oval, or round, or even squarish, very unequal. . . . . . 10. *S. longifolia.*

Resinous wood parenchyma numerous and often forming definite tracts.

Rays (tangential) very numerous, narrow; cells (1) uniform, oval, and chiefly equal throughout. . . . . . 11. *S. cordata.*

Resinous wood parenchyma confined to the limiting zone.

Rays (tangential) narrow, 1-seriate.

Ray cells (1) variable, oblong, narrow or more often broadly oval or squarish, unequal.

Vessels (transverse) at first broadly oval; 1- to 3- or finally 8-compounded and narrow. . . . . . 4. *S. nigra.*

Ray cells (1) uniform in the same ray but variable between different rays, narrowly oblong to oblong, chiefly equal.

Vessels (transverse) strongly predominant throughout, 2- to 3- or more rarely 4-compounded. . . . 5. *S. alba.*

Ray cells (1) somewhat variable, chiefly oblong or sometimes broadly oval; chiefly equal.

Vessels (transverse) strongly predominant, 2- to 5-compounded. 6. *S. lasiandra.*

Ray cells (1) chiefly uniform and oblong, sometimes oval; unequal, often twice as broad or twice as high.

Vessels (transverse) large, strongly predominant, 2- to 3- or rarely 4-compounded. . . . . . . 7. *S. lancifolia.*

Ray cells (1) uniform, oblong, chiefly equal.

Vessels (transverse) predominant, at first large, chiefly simple but 2- or very sparingly 3-compounded. 8. *S. brachystachys.*

Ray cells (1) narrow, chiefly uniform, oval or more generally oblong, equal.

Vessels (transverse) uniform in size and number throughout, except at the outer limits of the growth ring where they abruptly diminish in size; chiefly 1- often 2- to 3-compounded. . . . . . . 9. *S. scouleriana.*

Rays (tangential) broader, more or less 2-seriate.

Ray cells (1) uniform in the same ray, variable between different rays, oval or squarish, broad, unequal.

Vessels (transverse) predominant, 2- to 3- or more rarely 5-compounded. . . . . 1. *S. lævigata.*

Ray cells (1) uniform, oval, narrow, chiefly equal.

Vessels (transverse) single or somewhat 2- to 3-compounded. 2. *S. hookeriana.*

Ray cells (1) thin-walled, uniform, oblong, narrowly oval, equal.

Vessels (transverse) not predominant, 1- to 4-compounded, conspicuously fewer toward the outer limits of the growth ring. 3. *S. uva-ursi.*

1. *S. lævigata* Bebb.

Transverse.—Growth rings very broad; the limiting wood parenchyma about 3 cells thick, sparingly resinous. Vessels predominant throughout, at first rather large, radially oblong and very gradually reduced in size to the outer limits of the growth ring where they are about ¼ the original dimensions; 2- to 3- more rarely 5-radially compounded. Medullary rays numerous, resinous, prominent, 1 cell wide, distant upwards of 6 rows of cells.

Radial.— Rays resinous. Cells (1), the upper and lower walls thin and not pitted; the terminal walls finely pitted. Cells (2) sometimes predominant: the upper and lower walls thin and not pitted: the terminal walls finely pitted; the pits on the lateral walls forming a coarse sieve-plate structure.

Tangential.— Rays very numerous, medium to rather broad, 2-seriate in part, resinous. Cells (1) uniform in the same ray but variable in different rays, oval or squarish, unequal. Cells (2) uniform and narrowly oblong, strongly unequal, often several times higher than broad.

2. *S. hookeriana* Burr.

Transverse.— Growth rings very broad ; the limiting wood parenchyma composed of rather distant and resinous cells. Vessels rather numerous, single or somewhat 2- to 3-compounded, oval, very gradually diminishing in size to the outer limits of the growth ring where they are $\frac{1}{4}$ to $\frac{1}{3}$ the diameter of the first. Medullary rays numerous, slightly resinous, 1 cell wide, distant upwards of 8 rows of cells.

Radial.— Rays rather sparingly resinous. Cells (1) more resinous ; the upper and lower walls thick and very unequally, often sparingly pitted ; the terminal walls rather strongly though finely pitted. Cells (2) less resinous, the upper and lower walls rather thin and devoid of pits ; the terminal walls strongly and finely pitted ; the pits on the lateral walls minute, simple and often slit-like when opposite wood cells, but forming a coarse sieve-plate structure opposite vessels.

Tangential.— Rays numerous, resinous, sometimes 2-seriate in part, low to high, narrow. Cells (1) rather uniform and oval, chiefly equal. Cells (2) variable, narrowly oblong and more or less conspicuously unequal, rather thin-walled.

3. *S. uva-ursi* Pursh.

Transverse.— Growth rings narrow, variable, eccentric ; the limiting wood parenchyma rather resinous and prominent ; the wood cells thin-walled and squarish throughout with no obvious distinction of spring and summer wood. Vessels not predominant, 1- to 4-compounded and conspicuously few toward the outer face of the growth ring. Medullary rays 1 cell wide, very sparingly resinous, not prominent, distant upwards of 6 rows of wood cells.

Radial.— Medullary rays sparingly resinous. Cells (1), the upper and lower walls usually thin and not obviously pitted ; the terminal walls somewhat strongly pitted. Cells (2), the upper and lower walls thin and not obviously pitted ; the terminal walls finely pitted ; the pits on the lateral walls forming a strong sieve-plate structure ; strongly predominant.

Tangential.— Medullary rays low to medium, very narrow, sparingly resinous, 2-seriate in part, the cells chiefly thin-walled throughout. Cells (1) uniform, oblong, to narrowly oval ; equal. Cells (2) uniform, narrowly oblong, unequal, and often several times higher than broad ; usually predominant and often excluding (1).

4. *S. nigra* Marsh.

Transverse.— Growth rings broad, the inner region of the growth ring usually more dense; the limiting wood parenchyma sparingly resinous, in 1 to 2 rows of cells. Vessels numerous, large, rather broad, and oval, gradually diminishing in size and number toward the outer region of the growth ring and finally becoming few, narrow, and rather small; 1- to 3-compounded or in the outer portions of the ring often 8-compounded and narrow. Rays rather numerous, not very prominent, very sparingly resinous, 1 cell wide, and distant upwards of 8 rows of wood cells.

Radial.— Medullary rays locally resinous. Cells (1), the upper and lower walls rather thin and usually not obviously pitted; the terminal walls chiefly thin and devoid of pits. Cells (2), the upper and lower walls thin and devoid of pits; the terminal walls strongly but finely pitted; the pits on the lateral walls forming a strong sieve-plate structure.

Tangential.— Rays very numerous, medium, sparingly resinous, 1-seriate, and broad. Cells (1), variable, unequal, oblong and narrow or more often broad and oval or squarish; unequal. Cells (2) less resinous, variable but chiefly narrowly oblong, unequal, and differing in both height and width.

5. *S. alba* Linn.

Transverse.— Growth rings very broad, the limiting wood parenchyma 1 to 2 cells thick, resinous. Vessels strongly predominant throughout: large, oval, often oblong, chiefly single but often 2- to 3- or more rarely 4-compounded; not diminishing sensibly toward the outer face of the growth ring. Medullary rays numerous, somewhat resinous, 1 cell wide, distant upwards of 8 rows of wood cells.

Radial.— Rays sparingly resinous. Cells (1), the upper and lower walls thick, and strongly pitted throughout, the terminal walls generally curved and strongly pitted. Cells (2), the upper and lower and terminal walls strongly pitted; the pits on the lateral walls forming a strong sieve-plate structure; often approximating in height and general character to cells (1).

Tangential.— Rays resinous, numerous, narrow, medium. Cells (1) uniform in the same ray but variable in different rays, and ranging from narrowly oblong to oblong; chiefly equal. Cells (2) less resinous, uniform but unequal, differing greatly in height.

6. *S. lasiandra* Benth.

Transverse.— Growth rings broad; the limiting zone of wood parenchyma continuous, conspicuous and resinous, 1 to 2 cells thick. Vessels strongly predominant, radially and somewhat tangentially 2- to 5-compounded, steadily diminishing in size to the outer limits of the growth ring

where they are reduced to $\frac{1}{2}$ or $\frac{1}{3}$ the first size. Rays somewhat resinous, prominent, 1 cell wide, distant upwards of 6 rows of wood cells.

Radial.— Rays somewhat resinous. Cells (1), the upper and lower walls rather thick and often strongly pitted; the terminal walls thick and strongly though finely pitted. Cells (2) more resinous, often predominant; the upper and lower walls thin and not pitted; the terminal walls thicker and strongly though finely pitted, the pits on the lateral walls forming a prominent sieve-plate structure.

Tangential.— Rays numerous, resinous, narrow, chiefly medium. Cells (1) somewhat variable, chiefly oblong or again broadly oval; chiefly equal. Cells (2) uniform and narrowly oblong; very unequal and often several times higher than broad.

7. *S. lancifolia* Anderss.

Transverse.— Growth rings broad; the limiting wood parenchyma resinous and prominent. Vessels rather large and strongly predominant throughout, radially oval and 2- to 3- rarely 4-compounded; diminishing very gradually in size to the outer limits of the growth ring where they are about two thirds the first diameter. Medullary rays numerous, resinous, and prominent, 1 cell wide, distant upwards of 6 rows of cells.

Radial.— Rays resinous. Cells (1), the upper and lower walls thick and unequally though often strongly pitted; the terminal walls thick and strongly though finely pitted. Cells (2), the upper and lower and terminal walls thick and strongly pitted; the pits on the lateral walls forming a coarse sieve-plate structure.

Tangential.— Rays numerous, resinous, narrow, medium. Cells (1) chiefly uniform and oblong, but varying somewhat from oval to oblong; unequal and often twice as broad or twice as high. Cells (2) much less resinous, uniform, narrowly oblong, unequal.

8. *S. brachystachys* Benth.

Transverse.— Growth rings broad; the limiting zone of wood parenchyma not resinous. The wood cells large, rather thin-walled throughout. Vessels predominant throughout: at first large, radially oval, chiefly single but 2- or very sparingly 3-compounded; gradually diminishing in size to the outer limits of the growth ring where they become 2- to 5-compounded. Medullary rays numerous, non-resinous, 1 cell wide, distant upwards of 10 rows of cells.

Radial.— Rays non-resinous. Cells (1), the upper and lower walls rather thin and not obviously pitted; the terminal walls with very fine pits. Cells (2), the upper and lower walls thin and not pitted; the terminal walls some-

what thicker and very finely pitted; the pits on the lateral walls forming a coarse, sieve-plate structure.

Tangential.— Rays numerous, narrow, low to rather high, somewhat resinous. Cells (1) uniform, oblong, chiefly equal. Cells (2) uniform, narrowly oblong, very unequal, and often several times higher than broad.

9. *S. scouleriana* Bebb.

Transverse.— Growth rings medium; the limiting zone of wood parenchyma somewhat resinous, 1 to 3 cells thick. Vessels somewhat uniform in size and number throughout, except at the outer limits of the growth ring where they abruptly diminish in size; oval, rather broad, chiefly 1-, but frequently 2- to 3- more rarely 4-compounded. Medullary rays numerous, prominent, resinous, 1 cell wide, and distant upwards of 8 rows of cells.

Radial.— Medullary rays resinous. Cells (1), the upper and lower and terminal walls thick and strongly pitted throughout. Cells (2), the upper and lower and terminal walls rather thick and strongly pitted; the pits on the lateral walls forming a prominent sieve-plate structure.

Tangential.— Rays numerous, resinous, medium, narrow, 1-seriate. Cells (1) narrow, chiefly uniform, oval or more generally oblong, equal. Cells (2) uniform, narrowly oblong but very unequal, and often several times higher.

10. *S. longifolia* Muhl.

Transverse.— Growth rings usually very broad but very variable and sometimes very narrow. Wood parenchyma cells numerous, very resinous, and associated with the vessels as well as forming an open zone on the outer face of the growth ring. Vessels predominant throughout, especially in the earlier portions of the growth ring: at first rather large, oval, and 1- to 3-compounded, later somewhat reduced, round, and simple or somewhat 2-compounded. Medullary rays numerous, resinous, 1 to 2 cells wide, distant upwards of 6, or more rarely 10 rows of wood cells.

Radial.— Medullary rays resinous. Cells (1), the upper and lower walls sparingly pitted, the terminal walls strongly but finely pitted. Cells (2), the upper and lower walls rather thick but not obviously pitted, the terminal walls very strongly pitted: the pits on the lateral walls forming a coarse sieve-plate structure.

Tangential. — Rays very numerous, resinous, 2-seriate in part. Cells (1) very variable, from narrowly to broadly oval, or round, or even squarish, very unequal. Cells (2) uniform, narrowly oblong but unequal and generally with thinner walls.

11. *S. cordata* Muhl.

Transverse.— Growth rings broad, terminated by 2 to 3 rows of radially flattened, rectangular wood cells; the limiting wood parenchyma prominent,

resinous; the structure rather dense throughout. Vessels not predominant; at first very numerous and very resinous, quickly diminishing in number and thence constantly diminishing in size and number, and always distant, to the outer face of the growth ring; rather small, oval, sparingly 2- or more rarely upwards of 4-compounded; everywhere numerous. Resinous wood parenchyma cells numerous throughout; associated with vessels and scattering throughout the growth ring, often forming more or less definite and extensive tracts. Medullary rays very numerous, resinous, 1 cell wide, distant upwards of 10 rows of cells.

Radial.— Ray cells very resinous. Cells (1), the terminal walls very thick and very strongly pitted; the upper and lower walls sparingly if at all pitted except in the later portions of the growth ring. Cells (2), often predominant; the upper and lower walls thin and not pitted except in the later portions of the growth ring; the terminal walls strongly pitted; the pits on the lateral walls forming a coarse sieve-plate structure.

Tangential.— Rays very numerous, medium, narrow, resinous. Cells (1) uniform, oval, and chiefly equal throughout. Cells (2) variable, oblong, often very narrow and unequal, often several times higher than broad, the walls commonly thinner.

12. *S. lasiolepis* Torr.

Transverse.— Growth rings broad; the limiting wood parenchyma 1 to 4 cells thick, sparingly resinous. Vessels at first not strongly predominant; oval or oblong, steadily diminishing in size and finally much reduced; chiefly single throughout, but sparingly 2- to 3-compounded. Medullary rays numerous, locally resinous, 1 to 2 cells wide, distant upwards of 6 rows of wood cells.

Radial. — Medullary rays resinous. Cells (1), the upper and lower walls sparingly and unequally pitted, often devoid of pits; the terminal walls strongly but finely pitted. Cells (2), the upper and lower walls chiefly rather thin and devoid of pits; the terminal walls strongly pitted; the pits on the lateral walls forming a coarse sieve-plate structure often coalescing into a coarse scalariform structure.

Tangential. — Rays very numerous, medium, resinous, 1- to 2-seriate. Cells (1) variable, oval to oblong, and conspicuously unequal. Cells (2) less resinous, variable, and unequal, often high.

13. *S. sessilifolia* Nutt.

Transverse.— Growth rings broad; the limiting wood parenchyma 1 to 2 rows of cells broad, occasionally resinous and confluent with resinous wood parenchyma in the adjacent spring wood. Vessels numerous and predominant throughout; radially oval and variable in size; 1- to 2-, more

rarely 3-compounded, especially at the outer limits of the growth ring where they are diminished to ¼ size. Resinous wood parenchyma more or less prominent throughout the growth ring in association with the vessels. Medullary rays numerous, rather prominent and resinous, 1 cell wide, distant upwards of 10 rows of wood cells.

Radial.— Rays somewhat resinous. Cells (1), the upper and lower and terminal walls strongly though rather finely pitted throughout, more resinous than the next. Cells (2) less resinous, often predominant; the upper and lower walls rather thin and sparingly pitted; the terminal walls strongly though finely pitted; the pits on the lateral walls variable, hexagonal, and forming a coarse, sieve-plate structure which more commonly becomes an open scalariform structure through transitional forms.

Tangential.— Rays sparingly resinous, low to medium, numerous, narrow. Cells (1) chiefly uniform, narrow, oblong, equal. Cells (2) uniform, narrowly oblong, very unequal and often several times higher than broad, less resinous than (1).

14. *S. amygdaloides* Anderss.

Transverse.— Growth rings broad; the limiting zone of wood parenchyma 1 to 4 cells thick and not obviously resinous. Vessels broad, oval, at first predominant, soon diminishing slightly in size and number toward the outer face of the growth ring where they are again somewhat abruptly reduced in size; at first oval, rather broad, and 1- to 4-compounded; finally much reduced in size and width and becoming 4- to 5-compounded. Medullary rays numerous, 1 cell wide, not resinous, and distant upwards of 16 rows of wood cells.

Radial.— Medullary rays more or less resinous. Cells (1), the upper, lower, and terminal walls rather thin and finely, the first obscurely if at all pitted. Cells (2), the upper and lower and terminal walls rather thin, the last finely but conspicuously pitted; the pits on the lateral walls forming a coarse sieve-plate structure often coalescing to form an open scalariform structure.

Tangential.— Rays very numerous, resinous, medium, chiefly narrow, 1-seriate. Cells (1) somewhat variable, oval or chiefly oblong and narrow, more or less conspicuously unequal. Cells (2) chiefly uniform, unequal, often several times higher.

15. *S. discolor* Muhl.

Transverse.— Growth rings broad, the limiting zone of wood parenchyma chiefly resinous. Vessels predominant throughout, radially oval, and 2- to 4-, more rarely 5-compounded especially at the outer limits of the growth ring, where they are diminished to ½ size. Medullary rays resinous,

prominent and numerous, 1 cell wide; distant upwards of 6 rows of wood cells.

Radial.— Rays resinous. Cells (1), the upper and lower and terminal walls thick, strongly but finely pitted. Cells (2), the upper and lower and terminal walls thick, finely but strongly pitted; marginal and interspersed, often predominant; the pits on the lateral walls variable and hexagonal, and forming a coarse sieve-plate structure which often passes through transitional forms into a scalariform structure.

Tangential.— Medullary rays resinous, numerous, low to high. Cells (1) variable, oblong to broadly oval, and conspicuously unequal. Cells (2) chiefly uniform and narrow, but very unequal and often several times higher than long, terminal, and interspersed, often predominant.

LITERATURE.

BENTHAM, G., AND HOOKER, J. D.

'62–'83. Genera Plantarum. London: 3 vols.

BERRY, E. W.

:02a. Notes on the Phylogeny of Liriodendron. *Bot. Gaz.*, vol. 34, pp. 44–63.

BERRY, E. W.

:02b. Notes on Sassafras. *Bot. Gaz.*, vol. 34, pp. 426–450, pl. 18.

BERRY, E. W.

:01–:03. Notes on Liriodendron Leaves. *Torreya*, vol. 1, pp. 105–107; vol. 2, pp. 33–37; vol. 3, pp. 129–132.

BERRY, E. W.

:04a. Additions to the Flora of the Matawan Formation. *Bull. Torrey Bot. Club*, vol. 31, pp. 67–82, pls. 1–5.

BERRY, E. W.

:04b. The Cretaceous Exposure near Cliffwood, N. J. *Amer. Geol.*, vol. 34, pp. 254–260, pl. 15.

DE BARY, A.

'84. Comparative Anatomy of the Vegetative Organs of the Phanerogams and Ferns. Oxford: xvi + 659 pp.

GOODWIN, W. L.

'88. Ringed Trees. *Can. Rec. Sci.*, vol. 3, pp. 227–229.

GRAY, A.

'89. Scientific Papers of Asa Gray, selected by Charles Sprague Sargent. Boston and New York: 2 vols., viii + 397, iv + 503 pp.

Holm, T.
'90. Notes on the Leaves of Liriodendron. *Proc. U. S. Nat. Mus.*, vol. 13, pp. 15–35, pls. 4–9.

Holm, T.
'95. On the Validity of some Fossil Species of Liriodendron. *Bot. Gaz.*, vol. 20, pp. 312–316, pl. 23.

Knowlton, F. H.
'93. Annotated List of the Fossil Plants of the Bozeman, Montana, Coal Fields with Table of Distribution and Description of New Species. *Bull. U. S. Geol. Surv.*, no. 105, pp. 43–64, pls. 5–6.

Knowlton, F. H.
'98. A Catalogue of the Cretaceous and Tertiary Plants of North America. *Bull. U. S. Geol. Surv.*, no. 152, 247 pp.

Knowlton, F. H.
:00. Flora of the Montana Formation. *Bull. U. S. Geol. Surv.*, no. 163, viii + 118 pp., 19 pls.

Lesquereux, L.
'92. The Flora of the Dakota Group. (Edited by F. H. Knowlton.) *Monog. U. S. Geol. Surv.*, vol. 17, 400 pp., 66 pls.

Newberry, J. S.
'95. The Flora of the Amboy Clays. (Edited by Arthur Hollick.) *Monog. U. S. Geol. Surv.*, vol. 26, 260 pp., 58 pls.

Newberry, J. S.
'98. The Later Extinct Floras of North America. (Edited by Arthur Hollick.) *Monog. U. S. Geol. Surv.*, vol. 35, xvii + 295 pp., 68 pls.

Peirce, G. J.
:04. Notes on the Monterey Pine. *Bot. Gaz.*, vol. 37, pp. 448–445.

Penhallow, D. P.
:00. Notes on the North American Species of Dadoxylon, with Special Reference to Type Material in the Collections of the Peter Redpath Museum, McGill College. *Trans. Roy. Soc. Can.*, ser. 2, vol. 6, sec. 4, pp. 51–97, 18 figs.

Penhallow, D. P.
:04a. Observations upon some Noteworthy Leaf Variations and their Bearing upon Palæontological Evidence. *Can. Rec. Sci.*, vol. 9, pp. 279–305.

Penhallow, D. P.
:04b. Notes on Tertiary Plants. *Trans. Roy. Soc. Can.*, ser. 2, vol. 10, sec. 4, pp. 57–76.

Penhallow, D. P.
:04c. The Anatomy of the North American Coniferales together with certain Exotic Species from Japan and Australasia. *Amer. Nat.*, vol. 38, pp. 244–273, 331–357, 523–554, 691–723.

Sargent, C. S.

'94. The Silva of North America. Vol. 6, Ebenaceæ-Polygonaceæ. Boston: 124 pp., pls. 252–304.

Schimper, A. F. W.

:03. Plant Geography. Oxford: xxx + 839 pp.

Seward, A. C.

'92. Fossil Plants as Tests of Climate. London, Eng.

de Vries, H.

:05. Species and Varieties; their Origin by Mutation. Chicago: xviii + 847 pp.

Wallace, A. R.

'80. Island Life. London.

Ward, L. F.

'88. The Paleontologic History of the Genus Platanus. *Proc. U. S. Nat. Mus.*, vol. 11, pp. 39–42, pls. 17–22.

Ward, L. F.

'96. Some Analogies in the Lower Cretaceous of Europe and America. *U. S. Geol. Surv., 16th Ann. Rept.*, pt. 1, pp. 469–542, pls. 97–107.

Watt, G.

:01. A Plague in the Betel-nut Palms. *Agric. Ledg.*, no. 8, pp. 129 179, pl.

White, D.

:05. Fossil Plants of the Group Cycadofilices. *Smithson. Misc. Coll.*, vol. 47, pp. 377–390, pls. 53–55.

Wieland, G. R.

:03. Polar Climate in Time the Major Factor in the Evolution of Plants and Animals. *Amer. Jour. Sci.*, ser. 4, vol. 16, pp. 401–430.

Williamson, W. C.

'71. On the Organization of the Fossil Plants of the Coal Measures. I. *Phil. Trans. Roy. Soc. London*, vol. 161, pp. 477–509, pls. 23–291 (also later parts).

Errata.

Page 515, line 29, for "Proteaceæ which is preëminently," read Proteaceæ which thus appears to be. Line 30, for "19 : 0.00," read *1 : 0.41*.

Page 516, line 9, for "forty-seven" read *fifty*-seven.

Page 516, first line of table, Proteaceæ, for "19 : 0.00" read *1 : 0.41*; for "19" read *24*; for "0.00" read *10* and insert "the whole" in the nineteenth line after Araliaceæ.

MOMENTUM IN VARIATION.

F. B. LOOMIS.

Ever since the theory of evolution was grounded and the fact that each form and species is the result of accumulated variations from a less specialized ancestor, was established, this same variation has been scrutinized to find its causes and laws. Darwin made it more or less sporadic, and saw in the struggle for existence the factor which selected the useful variations and eliminated the less suitable innovations. Later, recognizing many features, especially ornamental characters, as not useful, he also proposed sexual selection as a second factor in determining the preservation of variations. Others, especially paleontologists, have been struck by the fact that variations are in a line, so that useful features develop rapidly; and second, by the frequency with which several lines of variation appear in a form practically simultaneously, all in conformity to the particular habitat and habit of the possessor. Further, remarkable convergences are found in animals of different groups when placed in the same habitat. These facts lead to two lines of thought: first, that the environment acts on the animal more than merely to select such variations as chance may offer; and second, that the animal in its life, by its habits, acquires characters which are handed to its offspring accentuated, and thus adaptive features are rapidly developed.

In the above an explanation is found for the development of useful characters, but there remain still two classes to be accounted for. First, those which in their early stages are of no account, but when developed become important (as the cusps on teeth); and second those which have developed to perform a useful function but in later forms have reached a degree of specialization which has proved either a hindrance or the destruction of the possessor. To this class also belong those features developed to a degree of perfection beyond the requirements of utility (sponge spicules, Radiolarian shells, some plant blossoms).

For instance in the early members of the family of saber-toothed tigers (Machærodidæ), the upper canine teeth are elongated and flattened, making in such forms as Dinictis and Hoplophoneus a most efficient weapon. However, the elongating went on gradually until in a form like Smilodon the great tushes reach far below the lower jaw, and to open the mouth wide enough to take in food below the weapons was practically impossible, so that most of the food probably went in between the

a *b* *c*

Fig. 1. — Series of saber-toothed tigers' crania. *a*, Dinictis ; *b*, Hoplophoneus ; *c*, Smilodon.

canines. At this stage the family, world wide in its distribution, died out.

Taking this as an illustration of a variation going beyond its utility, there seems to the writer to be but one adequate explanation, namely, that as a special feature develops it attains a momentum which tends to carry it beyond the point of greatest utility. In so doing it may become a hindrance even to the point of exterminating its possessor, or may merely attain a perfection, not detrimental, but without other explanation.

Let this be applied to various groups. In the Radiolarian shell enough symmetry to maintain the balance of the animal would be expected, but when a mathematical perfection is shown in the repetition of every spine and ray in marvelous complexity, something more than utility has been subserved. The same may be said of the flesh spicules of sponges. At first being merely a deposition of something spinous in the flesh, so as to be disagreeable enough to protect the sponge from being eaten by small animals, these spicules are later carried to the perfection of

symmetry. These, with the symmetry of sessile crinoids, sea anemones, and floating jelly-fishes offer illustrations of the carrying of a feature far beyond utility, toward perfect symmetry.

The molluscan Hippurites starts as a form which thickens its shells, one of them especially, apparently as a protective measure. But when the shell has reached a thickness of an inch it can hardly be considered useful to increase it further. However, these forms go on increasing in thickness to in some cases over a foot, using up the vitality which would otherwise be available for reproduction. Momentum seems to be the only reasonable explanation in such cases, and there are several (Coralliopsidæ, Gryphea, Caprinidæ, etc.).

Among Cephalopoda the complication of the edge of the septum of various Ammonites offers another case. A sinuous mar-

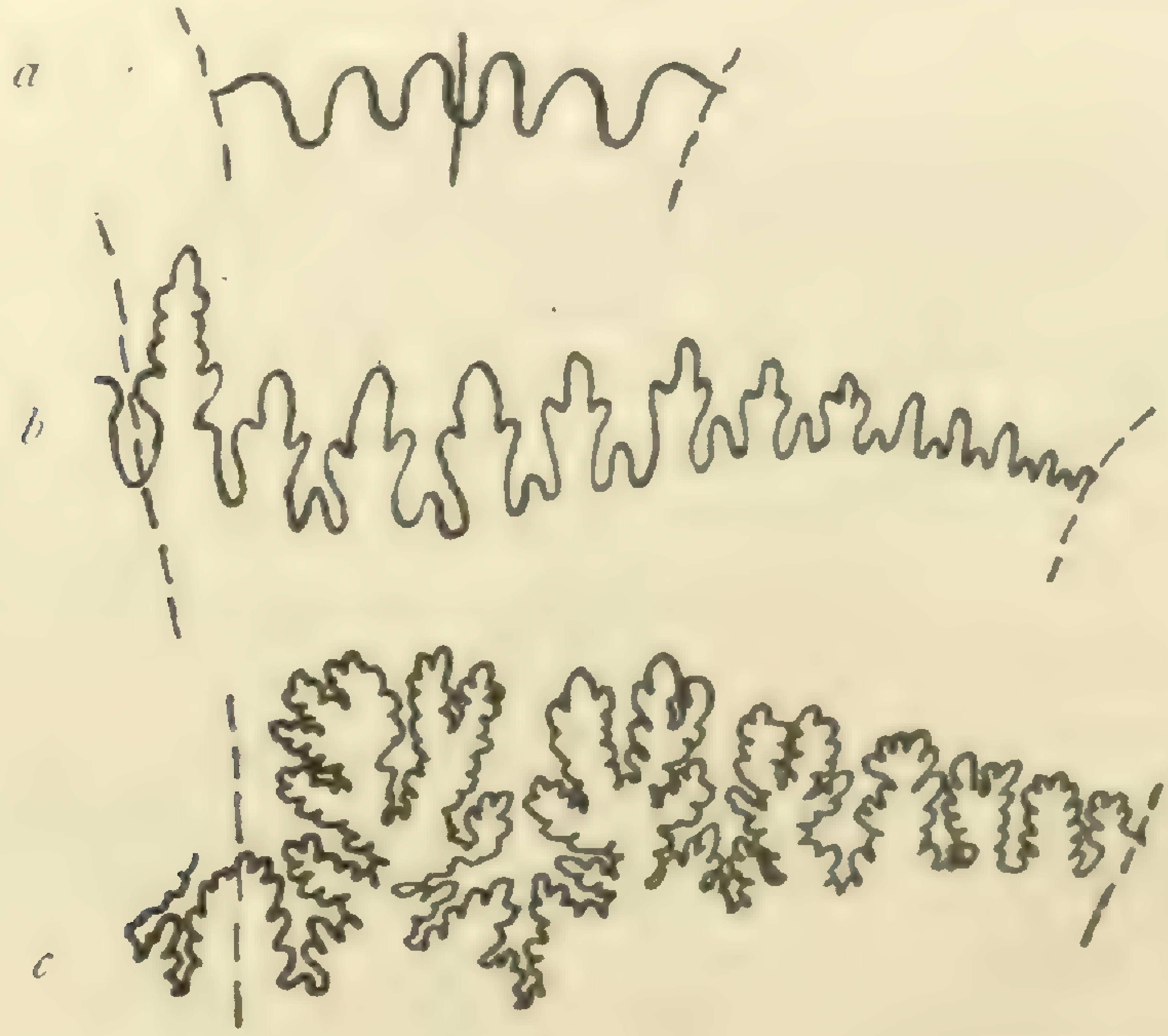

Fig. 2. — Series showing suture lines of Ammonites. *a*, Goniatites; *b*, Medliocottia; *c*, Desmoceras.

gin is doubtless a better brace against the pressure of the outside sea water, and such an irregular line as that of Goniatites or even Medliocottia (see Fig. 2) would be interpreted as useful. However, when it is carried to the complication found in Desmoceras or Pinacoceras, only momentum seems to explain the condition.

Turning to the vertebrates where the balance required for survival is even more delicate, the tooth of the Labyrinthodonts

is another instance. Here the surface is at first infolded probably for greater strength, but this is carried to a degree so complex as to be a puzzle to work out. Among the reptiles the Stegosaurian family adopted a dermal armor which some members developed till the double dorsal row of plates set on edge consisted of pieces some of which are over three feet across and several inches thick at the base. With such an excessive load of bony weight entailing a drain on vitality, it is little wonder that the family was short-lived. Doubtless the elongation of the snout was useful to the forms ancestral to Teleosaurus, but carried to the excess found in that genus, it resulted in a weak grasp, and the form disappeared.

Among the mammals the saber-toothed tigers have been mentioned. The mammoth with its extreme development of tusks may also serve to illustrate the principle. For, while at first the moderate tusk is an efficient weapon, as soon as it begins to be recurved as in *Elephas primigenius*, it loses its defensive value, and the carrying of the great weight is a drain on the vitality. A better example is seen in Babirusa where the canine teeth at first developed to protrude outward and of utility in digging, have gradually curved up over the snout, and appear more like horns than teeth. As they are now and were for a considerable portion of their previous development, they must be a serious hindrance in feeding.

The horns of many forms have also developed beyond usefulness. Take for instance those of the elk and moose, where if useful it is only in conflicts with other males once a year. But their great spread is a constant menace, requiring care lest in running they come to trees not far enough apart to admit of going between. Then the drain on the animal which sheds these great bony growths annually and replaces them again, is great. It is only as the result of momentum that these cases seem reasonable.

Among sheep where excessively heavy horns, such as those of the Kamchatka sheep and the big-horn, are developed, the great weight which lends force in butting can hardly be considered to offset the disadvantage which they entail in climbing and running. Wherever horns have been developed there seems to

be this tendency to carry them to excess, as in Titanotheres, Tinoceras, Elasmotheres, Irish elk, etc.

The above are selected examples in which a feature once useful has been developed beyond its maximum utility. Many others equally striking might be cited, the explanation of all of which is extremely difficult unless such a factor as momentum is called in. In the light of this factor, however, a logical and apparent cause is found. Momentum also explains why a character that originated in accordance with the environment develops so rapidly, and why, when an animal had reached adjustment to its surroundings, it still goes on beyond a perfect adjustment. It may be laid down as a rule then that *a variation started along any line tends to carry that line of development to its ultimate, being driven by momentum.* If the feature is detrimental the group dies out ; if, however, it is merely a minor feature it makes a handicap. A line of development may be stopped and its momentum overcome but the tendency is to keep right on.

This factor of momentum has not been given the importance due it, although it is felt in the undercurrent of the thought of several authors. It is the writer's belief, however, that it should find an important place in the explanation of animal structures.

AMHERST, MASS.

NOTES AND LITERATURE.

ZOÖLOGY.

A New Comparative Histology.[1] — The enormous mass of observations accumulated by histologists during the last decade has been greatly in need of such a treatment as would reduce its essentials to a compact and serviceable form. Schneider's *Lehrbuch der vergleichenden Histologie*, though a most excellent book in many respects, can scarcely be said to attack the problem from this standpoint, for its treatment of the subject on the basis of the descriptive histology of a series of representative animals has given to it so strongly an individual bent that it is a voluminous contribution from the author to comparative histology rather than a *résumé* of our present knowledge of that field. The *Traité d'Histologie* by Prenant, Bouin, and Maillard[1] on the other hand is a most successful attempt at this almost Herculean task. The work is planned for two volumes, of which the first, complete in itself, has just been published and the second is promised before the close of this year.

The first volume, whose subtitle is General and Special Cytology, is divided into three parts. The first of these includes Book I, dealing with protoplasm and the cell in general; Book II, giving the general morphology of the cell; Book III, taking up cellular physiology; and Book IV, indicating the lines of cellular differentiation. The second part, which contains Books V to VIII, has to do with the various forms of differentiated cells: sensory, muscular, nutritive, and sustentative. The third part includes Book IX on cell multiplication, X on individual reproduction, and XI on cellular degeneration and death. Each of these subjects has received an exhaustive and thorough treatment and not only are the facts concerning a given form of tissue well recorded but the present stand of the appropriate theoretic questions is unusually well stated. From the standpoint of a comparative histology which seeks to give the reader the main facts of the science and to orient him so far as the chief theoretic questions are concerned, the volume is without an equal and should prove a great boon to all histologists.

[1] Prenant, A., Bouin, P., et Maillard, L. *Traité d' Histologie. Tome I. Cytologie générale et spéciale.* Paris, C. Reinwald, 1904. xxxii + 799 pp., 791 figs.

In one respect the volume falls short of what it might have been. Little or no attention is given to the phylogeny of tissues and while this aspect of the subject is necessarily chiefly theoretic, a broadly grounded treatment cannot afford to omit it. Aside from this the volume is most acceptable. The presswork is excellent and the numerous figures, many of which are in color, afford a most ample body of illustrations for the text. There is a very full table of contents and an excellent index.

G. H. P.

Studies in Heterogenesis.[1] — One hundred years ago, Oken believed he had evidence that animal and vegetable tissues disintegrate after death to give rise by rearrangement of their elementary parts to minute living things which combine in larger and larger aggregates to form the myriads of infusion-dwelling microscopical organisms. Such an hypothesis is excusable with Oken in 1805, but in 1905, after more than sixty years of cell study, — after complete establishment of the dictum *omnis cellula e cellula*, the limit of toleration is overreached and we read with ever growing impatience the mass of so called evidence that dead protoplasmic substance is directly metamorphosed into living organisms of diverse species, genera, and even kingdoms.

This "evidence" is beautifully presented in 350 pages of letter press, with an appendix of 35 pages, and with 815 illustrations from microphotographs, by which, as the author tells us, the careful student can "help to break down the barrier of incredulity which at present excludes any general acceptance of the truth and universality of those processes of heterogenesis by means of which, as I believe, the lower forms of life, both animal and vegetal, are ever springing up anew in countless myriads from matrices wholly unlike themselves" (page 3). The photographs are fairly well taken and illustrate many common forms in stagnant waters but to present them as proof of heterogenesis recalls the *naiveté* of the small boy offering his pole and line as evidence of the ten-pound bass that escaped his hook.

Without going too much into details here, we may sum up the author's point of view by the following results which he believes are proved by his "evidence": —

1. Aggregates of bacteria in the zoöglœa stage may be transformed into fungus germs, or into Amœbæ, Mastigophora, or even into ciliated Infusoria (pp. 65–108).

[1] Bastian, H. C. *Studies in Heterogenesis.* London, Williams and Norgate, 1903. 8vo, ix + 354 + xxxvii pp., 19 pls. 31/6.

2. Ciliated Protozoa may be formed indifferently from such zoöglœa masses, or from the substance of Amœbæ (pp. 113–118), or from encysted Euglena (pp. 110–113), or from the eggs of Macrobiotus (pp. 138–144) and rotifers (pp. 44–45).

3. Diatoms, even, may arise *de novo* from the cells of a parasitic alga (pp. 158–168); or Actinophrys from the substance of Nitella cells, or from Euglena (p. 224). The latter, indeed, seems to be something of a protoplasmic Pandora's box from which emerge Peranema (p. 13), Polyphagus (p. 224), Olpidium (p. 226), Chytridium (p. 232), Chlamydomonas (p. 234), Amœba (p. 235), or higher algæ like Vaucheria (p. 188) and Conferva (p. 191), while its own protoplasm may be only the metamorphosed substance of an algal cell (Œdogonium).

As to the method employed in obtaining these remarkable findings there is little said; isolation and continuous observation were deemed unnecessary and fruitless. Tap water with hay for example, was heated to not more than 125° F. and left to stand. A scum developed after a few days, in which, from day to day, various types of organisms, including monads, fungus germs, Actinophrys, and even ciliates were observed, all having developed, he concluded, from "embryonal areas" of the scum. These observations are seriously presented as proving the heterogenetic origin of the different forms. Answering a criticism from certain "learned societies" that had refused to accept his conclusions based upon this method of observation, Bastian states: "I submit that such evidence as has been brought forward in this volume is the only kind of evidence that can be adduced in proof of heterogenesis" (p. 344), and this statement, if limited to his use of the term heterogenesis, is one and the only one in which we heartily and unqualifiedly agree with the author.

G. N. C.

Herrick's Home Life of Wild Birds.[1]—In the four years since the appearance of Professor Herrick's earlier work under this title, he has been able to extend his studies of nesting habits to a larger number of species and individuals, and in the present revised edition of his book "much has been re-written, and forty-eight new illustrations have been added to the text in place of a smaller number omitted. The first three chapters have been materially changed;

[1] Herrick, Francis H. *The Home Life of Wild Birds. A New Method of the Study and Photography of Birds.* New York and London, G. P. Putnam's Sons, 1905. 8vo, xxv + 225 pp., illus. $2.00.

Chapter XI. on Nest-Building is entirely new, as are also in large measure those which follow on The Development and Care of the Young and on Life and Instinct." The size of the volume has been reduced so as to make it serviceable for field use.

For the serious and minute study of the life of birds at their nests, the author's "method" has its great advantages as well as its limitations. A small tent, described fully in Chapter III, "Tent and Camera," is erected within arm's length of the nest to be studied and the observer is enabled to watch the activities of the birds through a small window cut at the proper height in the tent-wall. The camera is also used from the shelter of the tent. In cases where the nest cannot be conveniently reached from the ground it is removed together with the nesting-limb and set up in a favorable spot, where it may be readily observed from the tent. The instinct of the parent birds to care for their young is so strong that they soon return to their charges and, finding that no harm comes from the tent, they quickly learn to disregard it entirely. It is important to note, however, that such liberties may not be taken with a nest until the young are hatched and are a few days old, for if disturbed earlier than this the old birds will desert. For this reason the very early life of the nestling cannot be so well studied by this method. Professor Herrick has used his "method," with good judgment and in but "four or five cases when the nest with its supports has been displaced . . . . have the young come to grief, in the course of five years' work."

The first three chapters of the volume are given to an exposition of the "method," then follow chapters on the nesting habits of the robin, the cedar-bird, the red-eyed vireo, the bluebird, the catbird, the nighthawk, and the belted kingfisher, with photographic reproductions of the various activities that take place at the nest. The remaining chapters are of a more general nature and treat briefly of nest-building, the development and care of the young, life and instinct, and the instinct of fear in young birds. From his studies of a number of species, the author has come to regard a large part of the activities of nesting as instinctive. "Birds seem to follow one line of conduct, whether it be building nests, sitting over eggs, or brooding and tending the young, until their instinct in any given direction has been satisfied, thus normally completing one term of the series before passing to the next in sequence . . . . Each term of the cycle is capable of analysis into many minor components, differing not only in the sexes, but in different species, and subject to change in different individuals . . . . One instinct may be overdone, as when a bird like

the phœbe builds more than one nest, in which case her building instinct is apparently not satisfied by the usual exercise, or another may be scamped, as when swallows, house martins, or swifts desert their young in order to start on their migrations. When one instinct has been satisfied, wild birds must obey the next in sequence, which seems to possess them with the force of a resistless passion."

Apart from its interest as literature, the book from a purely scientific point of view, contains much of value with regard to the habits of certain of the species treated. Thus the nighthawk is found to feed its young, in one case at least, upon fireflies; the cleaning of the nest and removal of excreta is a duty regularly performed by the small birds studied; the parents do not attempt to feed each young bird in turn impartially, but often thrust food into a nestling's throat and withdraw it to try a second or a third young one until a bird with the "proper reaction time," *i. e.*, whose swallowing reflex is stimulated, is found. Brooding, or shielding the young from the heat, is part of the parents' duty on hot days, and it would be of interest to determine if this act is confined to birds that build open nests. Domed nests might be expected to dispense with the necessity for shielding the young from the sun's heat and possibly this may explain their origin.

The book itself is well printed and profusely illustrated. The style is popular but the author has used much judgment in his treatment of a field which "in the direction of both observation and experiment is of boundless extent, while on the side of inference it is full of pitfalls." The remarkable photographs by which the book is illustrated, add largely to its interest and value.

G. M. A.

Trouessart's Catalogus Mammalium, Supplement, Fasc. 4.[1] — The concluding part of this work, the first three fascicles of which have already been noticed in these columns (*Amer. Nat.*, vol. 39. pp. 603–605), lists the known living and fossil Cetacea, Edentata, Marsupialia, Allotheria, and Monotremata, and brings the total of known mammalian species up to 9381, an increase of 2157 over the number listed in the *Catalogus* of 1897–99. Among the Cetacea the great need for revisionary work is apparent and many of the species will doubtless be found to be merely nominal when more material can be

[1]Trouessart, E. L. *Catalogus Mammalium tam Viventium quam Fossilium. Quinquennale Supplementum (1899—1904)*. Fasc. 4. Berlin. R. Friedländer & Sohn, 1905. 8vo, pp. i–vii, 753–929. 8 Marks.

gathered and studied. Forster's name, *ampullatus*, revived by Rhoads (*Science*, N. S., vol. 15, p. 756, 1902) appears to have escaped the compiler, and seems applicable in place of *rostratus* for Hyperoödon. Four new generic names are proposed, to take the place of others that are preoccupied. Sphenodontherium for Sphenodon, Heterodontherium for Heterodon, and Propareutatus for Pareutatus among the Edentata, and Odontocyrtus for Kurtodon among the Marsupialia. The compiler also deems it necessary to amend the name Tatu to Tatus. The index includes those specific names only that have figured in works published since the previous catalogue.

G. M. A.

BOTANY.

Britton's Manual.[1] — In form, the recently issued second edition of this now well known work conforms closely to the first edition published in 1901. Analytical keys to the families, prepared by Wiegand, have been added to the prefatory matter, and a key to the genera of Compositæ, also prepared by him, has been placed at the end of the treatment of that family. The lamentable absence of necessary synonymy from the first edition has been rectified to a considerable extent; and in addition to such corrections as were possible in the original text, the appendix has been amplified by the incorporation of descriptions of over 100 species not recognized in the earlier edition, while, *e. g.*, under Cratægus, the fact that still others have been published is indicated.

W. T.

A New North American Flora.[2]—Since the appearance some years ago of the latest fascicle of the *Synoptical Flora* begun by Asa Gray, there has been no evident effort to provide a collective systematic treatment of the plants of the entire United States, though several handbooks covering a part of the country have appeared.

The fascicle now under review, though pertaining to a volume far

[1] Britton, N. L. *Manual of the Flora of the Northern States and Canada.* New York, Henry Holt and Co., 1905. 8vo, 2 ed., revised and enlarged, xxiv + 1112 pp.

[2] *North America Flora*, vol. 22, part 1.—Published by the New York Botanical Garden, May 22, 1905. Large 8vo, 80 pp. $1.50.

advanced in the series is in reality the initial number of a new work which is intended to describe the wild plants of all groups not only of the United States but of the remainder of North America, including the West Indies. The editorial management has been undertaken by Doctors Britton and Underwood, who have associated with themselves an advisory committee of representative American botanists, and who depend upon the collaboration of a large number of specialists. Thirty volumes of four or five fascicles each are in contemplation, and a special fund set aside for this purpose by the New York Botanical Garden provides for the publication of the several parts as they are prepared.

The present fascicle, which is attractively printed and provided with analytical keys for all of the groups treated, is devoted to the first four (Podostemonaceæ, Crassulaceæ, Penthoraceæ, and Parnassiaceæ) of the twenty-four families recognized as representing the order Rosales; the first being handled by Nash, the second by Britton and Rose, and the third and fourth by Rydberg, the ordinal key and description being by Small.

So large an undertaking is subject to many dangers and is certain to suffer many mishaps; and, considering the imperfect herbarium data and the impossibility of extensive field research if the work is to be pushed forward with any speed, it may be said that each fascicle is likely to become antiquated in a very short time after its publication, so far, at least, as the tropical regions are concerned, — the more rapidly, indeed, in proportion to its own critical excellence. There appears to be no other way, however, of making possible the ultimately complete flora of this enormous and botanically rich territory that every botanist feels the need of, and the editors should count on the active support of all who can help them forward with their plans.

W. T.

Ames's Studies in the Family Orchidaceæ.[1] — A new irregular-interval publication, somewhat comparable with *Hooker's Icones Plantarum*, the *Icones Selectæ Horti Thenensis*, etc., has been launched under the auspices of a publisher's house which does only good and attractive work. Its purpose is to present the results of investigation on one of the largest and best known collections of

[1] Ames, Oakes. *Orchidaceæ. Illustrations and Studies of the Family Orchidaceæ, issuing from the Ames Botanical Laboratory, North Easton, Massachusetts.* Boston and New York, Houghton, Mifflin and Co., 1905. 8vo, fasc. 1, vi + 156 pp., 16 pls.

orchids cultivated in the United States, its scope being limited to this family of plants. The first fascicle, issued on April 8, contains illustrations, critical notes, and technical descriptions covering a wide range of genera in the family and a number of countries. The most interesting feature for American botanists is a critical paper called "Contributions toward a Monograph of the American Species of Spiranthes," to which 33 pages are devoted.

W. T.

Notes.— The fourth of Rose's "Studies of Mexican and Central American Plants" (*Contributions from the U. S. National Herbarium*, vol. 8, part 4), like its predecessors is an important addition to the published information about the plants of the high tableland. The author states that none of the many new species it contains have been described until all their known Mexican relatives had been studied, and in most cases a synopsis of the genus prepared,— a procedure that speaks well for the conclusions reached.

A paper on plants eaten by the ancient Mexicans, by Urbina, has been published from the Museo Nacional of Mexico.

Nuttall's *Journal of Travels into the Arkansas Territory during the Year 1819, with Occasional Observations on the Manners of the Aborigines*, published at Philadelphia in 1821, is reprinted as vol. 13 of the *Early Western Travels* being edited by Dr. Thwaites of the Wisconsin Historical Society.

Under the title "Plant Migration Studies," Professor Bessey has distributed from *University Studies*, vol. 5, no. 1 (University of Nebraska) separates of an analysis of the distribution of Nebraska trees and the factors which have influenced it,— with 67 thumb-nail maps of the State, referring to as many trees.

The forest conditions of northern New Hampshire are considered by Chittenden in *Bulletin no. 55* of the Bureau of Forestry, U. S. Department of Agriculture.

A paper entitled "Additions to the Flora of Subtropical Florida," by Small, has recently been issued in the *Bulletin of the New York Botanical Garden*.

A contribution to the flora of the Bahama Islands, by Britton, is separately printed from vol. 3, no. 11, of the *Bulletin of the New York Botanical Garden*.

A monograph of Portuguese Orobanchaceæ, by Guimaraes, is published in *Broteria* for 1904.

Among other forest views, the *Report of the Forestry Bureau of the Philippine Islands* for the year ending September 1, 1903, recently issued, contains a good photogram showing the aërating roots of *Bruguiera caryophyllæoides.*

Mutation is discussed from various points of view in a series of papers printed in *Science* of April 7.

The megaspore membrane of Gymnosperms forms the subject of a paper by Thomson, published as no. 4 of the biological series of *University of Toronto Studies.*

Haywood publishes a paper on the injury to vegetation by smelter fumes, as *Bulletin no. 89* of the Bureau of Chemistry, U. S. Department of Agriculture.

The great scope of economic botanical study by the Government Bureau of Plant Industry, which spends annually nearly a million dollars, is well shown by the recently issued *Report of the Secretary of Agriculture for the Year ending June 30, 1904.*

The prickly pear and other cacti as food for stock are discussed by Griffiths in *Bulletin no. 74* of the Bureau of Plant Industry, U. S. Department of Agriculture.

A paper by Mann and Hunter on sisal-hemp culture in the Indian tea districts has been published recently by the Indian Tea Association of Calcutta.

An illustrated article on commercial Catalpa growing, by Gleason, is contained in *Country Life in America* for May.

Vol. 9 of the *Contributions from the U. S. National Herbarium* consists of an account of the useful plants of the island of Guam, by Safford.

Some large trees are noted and figured by Tavares in vol. 3 of *Broteria.*

The remarks of a number of biologists, chemists, and engineers on the use of copper sulphate for the purification of water supplies are published in *Science* of April 21.

The decays of timber due to higher fungi are reached in Lieferung 6 of Lafar's *Handbuch der Technischen Mykologie*, pertaining to volume 3.

The fungous diseases of orchard trees are considered by Wilcox in *Bulletin no. 132* of the Alabama Agricultural Experiment Station.

Three (edible) species of Coprinus are figured by Arthur in *Bulletin no. 98* of the Purdue University Experiment Station.

Sclerotinia padi and the diseases it causes are described by Lambert in an illustrated article in *Gartenflora* of April 1.

Nomenclatorial type specimens of plant species are discussed by Hitchcock in *Science* of May 26. In connection with some of the suggestions of this article should be read another, on general grounds, by Schuchert, in the same journal of June.

A noteworthy monograph of the genus Nymphæa, in quarto (xiii + 279 pp., 30 pls.), by Conard, has recently appeared as *Publication no. 4 of the Carnegie Institution of Washington.*

The development of *Sarracenia purpurea* is discussed by Shreve in *The Johns Hopkins University Circular*, no. 178.

Maiden's revision of the genus Eucalyptus has reached the 6th part, ending with p. 180 and pl. 32.

An anatomical study of *Croomia paucifolia* is published by Holm in *The American Journal of Science* for July.

A revision of the genus Zexmenia, by Jones, forms n. s., no. 30, of the "Contributions from the Gray Herbarium of Harvard University," published as vol. 41, no. 7, of the *Proceedings of the American Academy of Arts and Sciences*, issued June 23.

Stages in the development of *Sium cicutæfolium* are described by Shull in *Publication no. 30 of the Carnegie Institution of Washington.*

Recent publications on South American cacti are: Arechavaleta, "Flora Uruguaya," 2 entrega, forming part of the *Anales del Museo Nacional de Montevideo*; and Spegazzini, "Cactacearum Platensium Tentamen," in ser. 3, vol. 4, of the *Anales del Museo Nacional de Buenos Aires*, which Mr. Berger is summarizing in recent issues of the *Monatsschrift für Kakteenkunde.*

A paper on the haustoria of Santalum, by Barber, is published in *The Indian Forester* for April.

A paper on the development of *Phytolacca decandra*, by Lewis, is published in *The Johns Hopkins University Circular*, no. 178.

A preliminary paper by Johnson, on seed development in the Piperales and its bearing on the relationship of the order is published in no. 178 of *The Johns Hopkins University Circular.*

An account of the Jamaican species of Lepanthes, by Fawcett and Rendle, forms vol. 7, part 1, of the current botanical series of *Transactions of the Linnean Society of London.*

Teratological flowers of Agave are described by Maige in the *Revue Générale de Botanique* of April 15.

The North American species of Agrostis are revised by Hitchcock in *Bulletin no. 68* of the Bureau of Plant Industry, U. S. Department of Agriculture, under date of April 29.

A facsimile reprint of Cutler's "An Account of some of the Vegetable Productions naturally growing in this Part of America," from the first volume of *Memoirs of the American Academy of Arts and Sciences*, forms no. 7 (reproduction series no. 4) of the *Bulletin of the Lloyd Library*, issued in 1903.

An account of the vegetation of the "Sotol Country" in Texas, by Bray, forms *Bulletin no. 60* (scientific series no. 6) of the University of Texas.

An illustrated popular account of desert vegetation is given by Sharlot M. Hall in *Out West* for June.

Volume 9 of the "Flore de France" of Rouy, Foucaud, and Camus, published as the *Annales de 1904* of the Académie de la Rochelle, deals with Compositæ.

An account of new plants from the islands of Margarita and Coche, Venezuela, by Johnston, forming no. 29 of the new series of "Contributions from the Gray Herbarium of Harvard University," has recently been published as no. 21 of the current volume of *Proceedings of the American Academy of Arts and Sciences.*

A paper on the vegetation of Madeira, by Vahl, is contained in vol. 36, part 2, of Engler's *Botanische Jahrbücher.*

Vacciniaceæ and Ericaceæ (in part) are treated in the recently issued vol. 4, sect. 1, parts 1 and 2, of the "Flora Capensis" edited by Sir W. T. Thiselton-Dyer.

Papers on Indigofera (by Baker) and Aloë (by Schönland) are contained in vol. 1, part 4, of the *Records of the Albany Museum*, of Grahamstown.

The biological significance of leaf-fall is discussed by Wiesner in the *Berichte der deutschen botanischen Gesellschaft* of May 25.

A review of the identifications of the species described in Blanco's *Flora de Filipinas*, by Merrill, constitutes no. 27 of the publications of the *Bureau of Government Laboratories*, Manila, bearing date of April, 1905.

A paper by Pond on the biological relation of aquatic plants to the substratum has been separately issued, recently, from the *U. S. Fish Commission Report for 1903*.

Duggar's St. Louis address on present problems in plant physiology is printed in *Science* of June 23.

A translation, by Lloyd, of Gœbel's St. Louis address on the fundamental problems of present-day plant morphology is published in *Science* of July 14.

The mutations of Lycopersicum are discussed by White in *The Popular Science Monthly* for July.

A thesis on fruit and vegetable colors, by LaWall, is published in *The American Journal of Pharmacy* for July.

An important paper on the fly-galls of Juniperus is published by Howard in vol. 1, no. 2, of the ninth series of *Annales des Sciences Naturelles — Botanique.*

A paper on the morphology and anatomy of the stem of Lycopodium, by Jones, forms vol. 7, part 2, of the current botanical series of *Transactions of the Linnean Society of London.*

An extensive paper on the development of the ascus and spore formation in Ascomycetes (Contribution no. 61 from the Cryptogamic Laboratory of Harvard University) is published as vol. 32, no. 4, of the *Proceedings of the Boston Society of Natural History.*

The recently issued 17th volume of Saccardo's *Sylloge Fungorum* forms part 6 of the *Supplementum Universale* to the original work.

Postembryonal stages of the Laminariaceæ are described by Setchell in vol. 2, no. 4, of the *University of California Publications — Botany.*

A short paper on some Yellowstone diatoms is published by Edwards in *Nuova Notarisia* for July.

The cell structure of Cyanophyceæ forms the subject of a paper

by Fischer, published as no. 4–6 of the 63d volume of the *Botanische Zeitung, I Abtheilung.*

No. 8 (Mycological series no. 3) of the *Bulletin of the Lloyd Library*, dated April, 1905, contains an account by C. G. Lloyd of the Lycoperdaceæ of Australia, New Zealand, and neighboring islands.

An important paper connecting many Fungi Imperfecti with Ascomycetous forms has been published by Klebahn in vol. 41, heft 4, of the *Jahrbücher für wissenschaftliche Botanik.*

"Asparagus and Asparagus Rust in California" is the title of a well illustrated paper by Smith, published as *Bulletin no. 165* of the Agricultural Experiment Station of that State.

A paper on the grain-rust epidemic of 1904, by Carleton, forms *Farmers' Bulletin no. 219* of the U. S. Department of Agriculture.

Atkinson and Shore have published an illustrated paper on mushroom growing for amateurs as *Bulletin no. 227* of the Cornell University Agricultural Experiment Station.

A paper on apple scab and cedar rust, by Emerson, forms *Bulletin no. 88* of the Agricultural Experiment Station of Nebraska.

Orchard diseases are discussed by Wilcox in *Bulletin no. 132* of the Alabama Agricultural Experiment Station.

A popular summer key to our trees, by Julia Ellen Rogers, is published in *Country Life in America* for July.

Volume 3 of Marshall Ward's *Trees* deals with flowers and inflorescences, descriptively treated with reference to British forms.

Alwood, Davidson, and Moncure describe the composition of cider as determined by dominant fermentation with pure yeasts, in *Bulletin no. 150* of the Virginia Agricultural Experiment Station.

An agricultural-geographical study of rubber plants, with map, by Reintgen, forms no. 2–3 of the current volume of *Beihefte zum Tropenpflanzer.*

An account of native and introduced saltbushes, by Elias Nelson, forms *Bulletin no. 63* of the Wyoming Experiment Station.

The Mexican "guayule" (*Parthenium argentatum*) used as a source of caoutchouc, is the subject of an article by Endlich in *Der Tropenpflanzer* for May.

A well illustrated article by Fullerton, on "Roots We Eat," is contained in *Country Life in America* for July.

The wild legumes of Maryland are considered by Norton and Walls in *Bulletin No. 100* of the Maryland Agricultural Experiment Station.

A first paper on Wyoming forage plants and their chemical composition, by Knight, Hepner, and Nelson, forms *Bulletin no. 65* of the Wyoming Experiment Station.

A paper by Laurent on the "Flore pliocène des Cinérites du Pas-de-la-Mongudo et de Saint-Vincent-la-Sabie (Cantal)" forms vol. 9, part 1, of the *Annales du Musée d' Histoire Naturelle de Marseille.*

The Journals. — *Botanical Gazette*, April:— Thaxter, "A New American Species of Wynnea"; Shoemaker, "On the Development of *Hamamelis virginiana*"; Christman, "Sexual Reproduction in the Rusts"; Whitford, "The Forests of the Flathead Valley, Montana"; Livingston, "Note on the Physiology of Stigeoclonium"; Trow, "Fertilization in the Saprolegniales."

Botanical Gazette, May:— Dean, "On Proteolytic Enzymes — I"; Cardiff, "Development of Sporangium in Botrychium"; Livingston, "Physiological Properties of Bog Water"; Darbishire, "An Apparatus for observing the Transpiration Stream"; Lyon, "Polyembryony in Sphagnum"; Maxon, "Adenoderris, a Valid Genus of Ferns."

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DEVOTED TO THE NATURAL SCIENCES
IN THEIR WIDEST SENSE

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THE

AMERICAN NATURALIST.

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ECOLOGY OF THE WILLOW CONE GALL.

ROY L. HEINDEL.

Among the numerous galls to be found everywhere, the cone galls of the willows are very common forms. A little has been done toward their knowledge by Walsh, who has dealt more particularly with descriptions of the galls and their makers and has done little more than make casual mention of ecological relations. An examination of the galls in fall or winter shows them to be the abiding place of the larvæ of a goodly number of insects. Walsh says: "Nothing gives us a better idea of the prodigious exuberance of insect life, and of the manner in which one insect is often dependent upon another for its very existence, than to count up the species which haunt, either habitually or occasionally, one of these willow-galls, and live either upon the substance of the gall itself or upon the bodies of other insects that live upon the substance of the gall."

In the following pages will be discussed, first, the galls themselves, second, the gall makers, and third, the guests and parasites that inhabit the galls.

The Cone Galls.

As is well known, a gall is some abnormal growth of a plant tissue resulting from an external stimulus. In the case of the cone galls and of the other bud galls of the willow the stimulus is furnished by the gall gnat. Whether it is given by the insertion of the ovipositor into the bud, by the presence of the egg, or by the larvæ, I cannot say. The gall attains its full growth by midsummer thus giving evidence of considerable stimulation. Regularity and symmetry in the shape of the gall can be accounted for by the stimulus, whatever it may be, acting equally in every direction.

As a result of this stimulus, the bud takes on a remarkable

a *b* *c* *d* *e* *r*

Fig. 1.—Cone gall of Salix. *a*, *b*, *c*, *Salicis gnaphaloides* (showing variation in crook of stem); *d*, *Salicis strobiliscus*; *e*, *f*, *Salicis strobiloides*.

activity in growth, and develops a large number (60–75) of scales. These scales are placed in regular order, with their edges overlapping, and form in the center an elongate cell. This cell, protected by the numerous layers of scales, is the abiding place of the gall maker during its larval and pupal stages.

The three cone galls on which I have based most of my study are all found in the vicinity of Lake Forest, Illinois. I also gathered some material in southwestern Wisconsin. They are formed from apical buds. In structure and appearance they are much alike but they have some characteristic differences. The three are: —

1. A pubescent gall found growing on *Salix cordata* Muhl., which corresponds in every particular to the gall found by Walsh on the same willow. This is the gall *Salicis strobiloides* O. S. (Fig. 1, *e* and *f*). It is usually somewhat spherical but occasional galls have the central scales prolonged into a loose tip. It is the dense silvery pubescence which distinguishes this gall most clearly from the others.

2. A cone gall usually more tapering than the above and lacking the dense pubescence. Its marked characteristic is a decided curve or bend in the twig just beneath the gall (Fig. 1, *a*, *b*, *c*). In every respect the gall corresponds to *Salicis gnaphaloides* Walsh, but in no case have I found it on *Salix humilis*, the willow to which Walsh accredits it. Instead, I have found it in great abundance on *Salix bebbiana*.

3. A gall corresponding exactly to *Salicis gnaphaloides*, except that the twig is straight (Fig. 1, *d*), was also found on *Salix bebbiana*, the *Salix rostrata* of Walsh's paper. These galls were not in such great abundance and were usually to be found on the same plant with the gall *S. gnaphaloides*. In some two or three cases small shrubs bearing only a few galls had all straight-stemmed ones. On one shrub with 37 galls, 9 were straight and 28 were crooked. From another clump of willows (*S. bebbiana*) I gathered 65 galls, of which 57 were crooked and only 8 straight. In both cases there was a gradation in the matter of the crook.

Since I shall show a little farther on that these three galls have the same maker, it is evident that the distinction between the first and the others may be due to the peculiar reactions of the different willows to the stimulus which causes the growth of the gall. But in the case of the two galls on *S. bebbiana* the cause of the difference does not seem so clear. It will be necessary to observe the beginning of the gall to see if this can be determined.

In his *Origin of Floral Structures*, Henslow has drawn an analogy between the gall and the flower. He intimates that the gall is the result of the shortening of the axis due to puncturing in the depositing of eggs by insects, and thus represents a lessened growth of twig. I believe that the gall does not represent a shortening of the axis, but, on the other hand, represents a special growth of scales in addition to the normal growth of twig. I base my belief on the following observations: —

1. The scales of the gall have not the normal leaf arrangement or venation. From a single clump of willows (*S. bebbiana*) I gathered a number of twigs and galls. The lateral buds of this willow have the two fifths arrangement. If the gall represents a shortening of the axis the scales ought to show some such arrangement, allowing for a reasonable amount of displacement owing to crowding. While the general arrangement of the scales was in whorls, some showed a spiral arrangement but never the two fifths. I examined in detail about a dozen galls to determine this. Moreover the scales do not very much resemble the leaves of the willows. They differ in shape and margin and show little or no venation and never the venation of the leaf.

2. The gall-bearing shoot is oftenest longer than the non-gall-bearing and develops more lateral buds. From this same bunch of twigs I took 28 bearing the crooked galls and the same number of non-gall-bearing twigs. The average number of lateral buds to the gall-bearing twigs was 20, while the average to the non-gall-bearing twigs was only $16\frac{1}{4}$. Eleven gall-bearing and ten non-gall-bearing twigs were taken from the same part of the plant, having had, as nearly as could be determined, the same conditions of growth. The former had an average of $17\frac{4}{11}$ lateral buds and an average length, from origin of the twig to the base of the gall, of 6.84 inches, and the latter had an average of 17 lateral buds and an average length to base of terminal bud of 6.825 inches. In every case the twigs were of 1904 growth. General observations of various clumps of willows confirmed the foregoing results. However, in one case the average length of five pubescent gall twigs (*Salix cordata*) was 1.13 inches less than the average length of seven non-gall-bear-

ing twigs growing under similar conditions. The former averaged three more lateral buds to a twig than the latter. From another clump of willows 14 twigs bearing pubescent galls had an average of three buds fewer than 14 non-gall-bearing twigs (15 and 18) but the average length was equal.

I conclude that the gall does not represent a shortening of the axis and that the gall-bearing twig does not represent a lessened growth, but that, on the other hand, the gall-bearing

FIG. 2.— Two cone galls showing extremes in size. The larger shows protruding pupal skins of the moth Acleris. At the base of the crooked stem of the smaller is a bud favorably placed for continuing growth in a direct line.

twig holds its own with the non-gall-bearing and has in addition the abnormal growth of the gall.

The very abnormal shape of the stem of the crooked gall suggests a question as to its purpose. Since the gall terminates the twig and prevents further apical growth, future growth must

be by means of a branch originating on the twig below the gall. At first it appears as if the crook in the stem (see Fig. 2) might provide for a direct growth by means of a branch from the convex side of the stem. Dr. P. Speiser claims that a bend in the stem is of advantage in this way in the gall *Dichelomyia rosaria* H. Lw., since the gall is turned aside, and thus permits a more or less direct growth from a bud below it. An examination of any willow bearing these crooked galls (*S. gnaphaloides*) shows very plainly that the benefit for continued growth is accidental rather than habitual. To be of service it would be necessary that a bud be located just at the beginning of the crook in the stem. In one lot of 57 galls, 32 had buds so located and 25 were without bud in a favorable position. By watching the willows for further information, I found that very frequently the favorably placed bud either does not develop or sends off a branch at an angle from the parent twig. And just as frequently, when there is no bud so favorably located, a bud farther down, or one immediately beneath the gall, is the one which sends out the most vigorous branch, whose direction is determined by its surroundings.

The Gall Makers.

The life history of the gall gnat is very simple. In the spring the larva which has spent the winter in its cell in the gall transforms into the pupa and that, a little later, into the gall gnat itself. The gnats soon deposit their eggs in apical buds of willows. From the eggs larvæ are hatched and the cycle begins again. Walsh speaks of observing larvæ as late as April 23, and pupæ from early in April until late in May. From galls gathered and examined on the following dates I found larvæ of the gall gnats: October, November 12, December 26, January 17, February, about March 20, and the first and second weeks of April. In March and April, many larvæ were almost ready for transforming into pupæ but only a few pupæ were found. Gnats had emerged from all the galls examined June 3. I kept some of the galls gathered in December and on subsequent dates, to watch for transformations. From those of December 26, one or

two gnats emerged about the middle of February. From those of March 20 several gnats emerged early in April. From the April specimens they began to appear within a week and continued to emerge for over three weeks. Because of the difficulty in rearing gall gnats my data are not complete. But it is evident that the insect exists for a long time in the larval state and that the pupal period is comparatively short.

Walsh found it difficult to devise an artificial mode of treatment for rearing the gall gnats in the house. My results with

FIG. 3.— Gall gnat (*Rhabdophaga strobiloides* O. S.) enlarged.

the earlier lots of galls were not very successful. At first I threw them in jars and boxes but found that in a short time larvæ and pupæ dried up in many of the galls. Then I tried keeping them with the stems in water but with scarcely better success. With the last lot I used a different plan. I tied the galls in squares of cheese cloth, opening the bundles and sprinkling them every day or two. This plan was very successful. Of course it is possible that the season had something to do with it, for it was nearly the regular time for the emerging of the gnats. But that cannot be the full explanation, for, in packages which were neglected, the results were less satisfactory. The sprinkling seems to have taken the place of the spring showers.

Cecidomyiids offer considerable difficulty in the matter of

specific determination. Walsh has called the maker of each of the fifteen willow galls he describes a distinct species. If the galls themselves could be taken as a means of determining species his results would in most cases stand. Although I have been working with only a few of the cone galls, it is necessary to consider some others in settling this question.

Of Walsh's fifteen willow galls, six are more or less cone-shaped bud galls of somewhat similar structure. The larvæ found and described by Walsh in these six are precisely alike as to size, shape, "breast bone," etc. Walsh gives, however, the following differences in the cocoons: —

Cecidomyia salicis brassicoides, cocoon scarcely larger than larva.

Cecidomyia salicis strobiliscus, cocoon $1\frac{1}{2}$ to 2 times as long as larva.

Cecidomyia salicis gnaphaloides, cocoon $1\frac{1}{2}$ to 2 times as long as larva.

Cecidomyia salicis coryloides, cocoon 2 times as long as larva.

Cecidomyia salicis strobiloides, cocoon $2\frac{1}{2}$ to 3 times as long as larva.

Cecidomyia salicis rhodoides, cocoon $2\frac{1}{2}$ to 3 times as long as larva.

The difference seems to be considerable but it is easily explained. I have examined all except the fourth (*coryloides*), ten or more galls of each, and have found the length of the cocoons to vary in the different galls in proportion to the length of the central cell or cavity (see Fig. 5). The gall *S. brassicoides* has a short cell which permits of only a short cocoon, while the gall *S. strobiloides* has a long central cell giving plenty of space for a long cocoon. If the cocoon is exuded from the larva and is expanded by a gas, as Walsh supposed, then the length and size of the central cell certainly would determine the size of the cocoon.

In these same six species Walsh found the pupæ of only five. The only difference I can find in his descriptions is that *C. s. gnaphaloides* (in dried specimens) is slightly shorter than the others. I could not find this difference.

From a careful comparison of Walsh's descriptions and from

verifications by observation in the case of the cocoons of five of the galls and in the case of the larvæ and pupæ of three of them, I am convinced that specific differences, if any, must be looked for in the imagoes, for they cannot be found in the earlier stages.

Imagoes of the makers of five bud galls were found and described by Walsh. I give below a table showing the differences which he finds in them.

Imagoes of Bud Gall Makers.

Species	*brassicoides*	*strobiloides*	*strobiliscus*	*gnaphaloides*	*rhodoides*
Antennal Joints	22–24	21–22	23–24		21–25
Thoracic Hairs	Dusky	Whitish	Whitish	Whitish	Whitish
Length in Inches	0.16–0.20	0.16–0.20	0.16–0.20	0.12–0.15	0.16–0.20
Origin of Anterior Branch of Cubital Wing Vein	Occasionally obsolete	Always obsolete for a short space	Rather distinct	Rather distinct	Occasionally obsolete

The variation in the number of antennal joints makes that feature useless as a specific characteristic. Antennæ of dried specimens are easily broken, but by using fresh and alcoholic specimens, I find that there are about the same number of joints in those of all the gnats which make the different galls.

The color of thoracic hairs is the first and only distinguishing characteristic. I have had only five imagoes of *C. s. brassicoides* Walsh but find that the dusky hairs are present in all, while in the gnats from the four other galls the thoracic hairs are whitish.

Length shows no difference except in the one case, and I think this cannot be considered for I found four, from one lot of five imagoes from the gall *S. gnaphaloides*, which were fully 0.21 inches in length, and I have found but one or two as short as 0.12 inches.

As to wing venation the wings of four *C. s. brassicoides* Walsh have the origin of the anterior branch of the cubital vein distinct. Seventeen left and eighteen right wings of *C. s. strobiloides* Walsh gave the following results as to the origin of the anterior branch of the cubital vein: —

Origin of 16 anterior veins obsolete.
Origin of 6 anterior veins very indistinct, probably obsolete.
Origin of 4 anterior veins indistinct, probably not obsolete.
Origin of 9 anterior veins distinct.

These results do not agree with Walsh's statement but, on the contrary, show that this feature of the wing venation cannot be taken as a specific characteristic. Wings of five *C. s. gnaphaloides* Walsh and two *C. s. strobiliscus* Walsh have the origin of the anterior branch very distinct. Four *C. s. rhodoides* Walsh show it "occasionally obsolete" as given by Walsh. The fact that variations do occur and that each of the so called species has some individuals with the venation like that of other species is sufficient to throw this out as a determining characteristic. Walsh says himself that the imagoes of his *gnaphaloides* and *rhodoides* are indistinguishable except for size, and I have shown that this difference is not fixed.

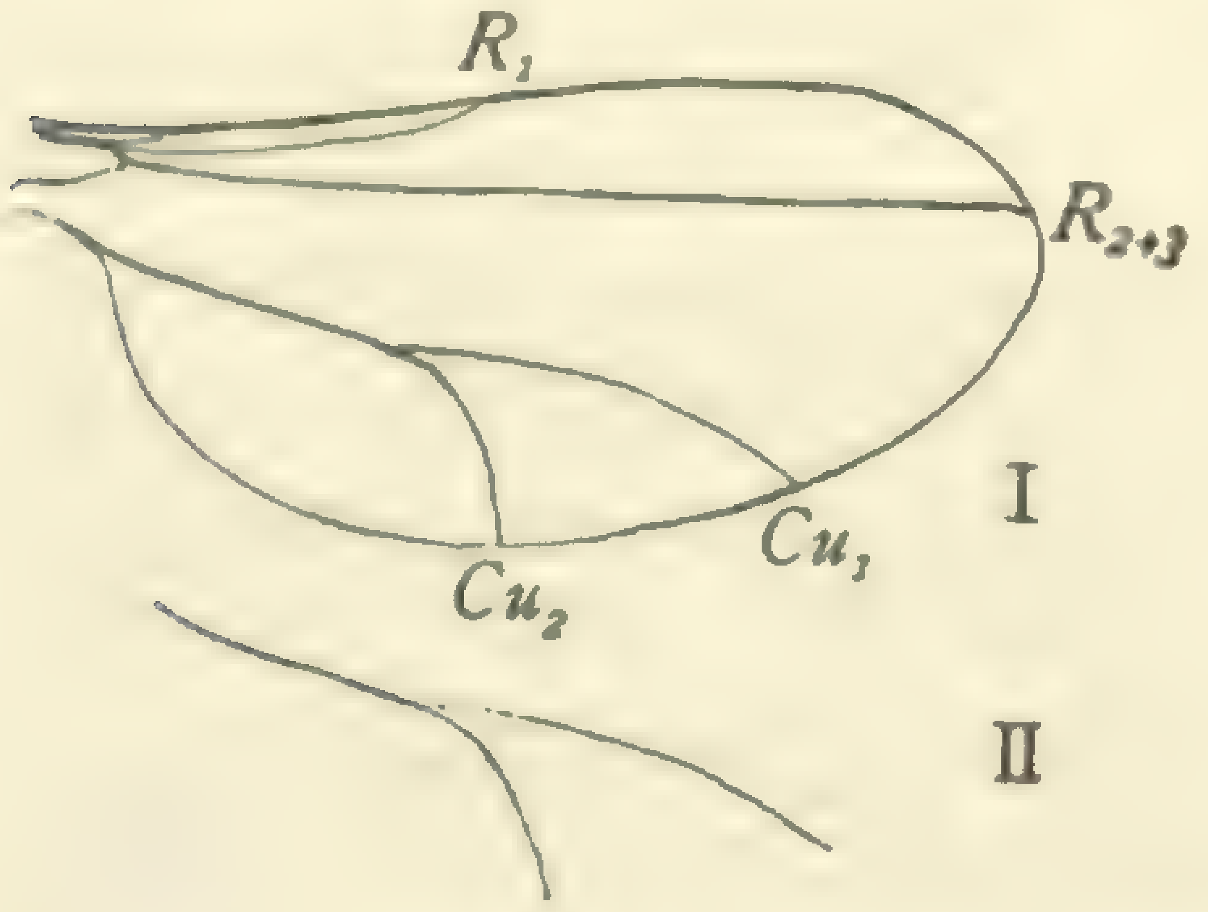

FIG. 4.— Wing venation of gall gnat. Cu_1, Anterior branch of cubitus. I. Origin distinct II. Origin obsolete.

His *brassicoides* differs from the others in having dusky instead of whitish thoracic hairs. Since the few specimens I have had showed this same difference, it is necessary, at least until other material is available, to let *C. brassicoides* stand as a distinct species. But from the data I have given and from the comparison I have made of Walsh's descriptions with each other and with my specimens, I must conclude that *strobiloides*, *strobiliscus*, *gnaphaloides*, and *rhodoides* are synonymous. Since the first name was given by Osten Sacken in 1861, I have taken it as the name of the species and the three others as synonyms. So the gnat which produces the four galls, *Salicis strobiloides*, *Salicis strobiliscus*, *Salicis gnaphaloides*, and *Salicis rhodoides* is *Rhabdophaga strobiloides* O. S. This verifies the inference of Bergenstamm and Löw that Walsh's species are all *strobiloides*.

Summarizing, *Rhabdophaga strobiloides* O. S. produces: gall

Salicis strobiloides on *Salix cordata*; gall *Salicis strobiliscus* on *Salix bebbiana*; gall *Salicis gnaphaloides* on *Salix bebbiana*; gall *Salicis rhodoides* on *Salix humilis*.

Guests and Parasites.

While I was gathering material for the study of the gall gnat I bred as many as possible of the other insects which inhabit the galls. These include not only the inquilines and the transient guests, but also a number of parasites which live on these inquilines or on the gall maker.

In making my table of results I have included a few species bred by Professor J. G. Needham from cone galls and from the galls *S. rhodoides* and *S. brassicoides* during the spring of 1904.

List of Insects bred from Galls.

	Gall *S. strobiloides*	Gall *S. gnaphaloides*	Gall *S. strobiliscus*	Gall *S. rhodoides*	Gall *S. brassicoides*
Gall makers:					
Rhabdophaga strobiloides O. S.	×	×	×	×	
Rhabdophaga brassicoides Walsh					×
Inquilines:					
Cecidomyia albovittata Walsh	×	×	×		
Chaitophorus sp. (plant louse)	×	×	×		
Pontania pisum Walsh (saw fly)	×	×	×		
Euura noda Walsh (saw fly)	×	×			
Xiphidium ensiferum, eggs (meadow grasshopper)	×	×	×		
A spring-tail (Thysanura)	×	×	×		
Acleris heindelana Fernald (a moth)		×			
Larvæ of a Noctuid (Lepidoptera)		×	×		
Larva of Tineid (?) (Lepidoptera)		×			
Larva of *Thyridopteryx ephemeræformis* (?) (Lepidoptera)		×			
Parasites and hyperparasites:					
Tetrastichus sp.	×	×			×
Tetrastichus sp.	×	×			×
Tetrastichus sp.	×				×
Polygnotus salicicola Ashm. (a Proctotrupid)	×	×			×
Eurytoma studiosa Say (a Chalcid)	×	×			×
Pteromalus sp. (a Chalcid)	×		×		
Torymus popenoi Ashm. (a Chalcid)	×				×
Aphanogmus virginiensis Ashm.	×	×			

Lists of Insects bred from Galls. (*Continued.*)

	Gall *S. strobiloides*	Gall *S. gnaphaloides*	Gall *S. strobiliscus*	Gall *S. rhodoides*	Gall *S. brassicoides*
Aphelinus mytilaspidus Le Baron (a scale parasite)		×		×	
A Campoplegine	×				
An Encyrtine	×				×
Copidosoma intermedium How.	×				×
Urogaster forbesii Ashm.	×				
Tridymus metallicus Ashm.		×			×
Dapanus n. sp. (an Ichneumonid)	×				
Oncophanes n. sp. (a Braconid)	×				
Transient and accidental guests:					
Megalothrips sp.	×				
Phlœothrips sp.	×				
Ischnorhynchus resedæ Panzer (Heteroptera)	×				
Triphleps insidiosus Say (Heteroptera)		×			
A pseudoscorpion		×			

Thus we find at least 32 species of insects making use of the cone galls. Of these, one is a gall maker, 10 are inquilines, 16 are parasites or hyperparasites, and 5 are transient or accidental guests. It will be noticed that the greater number are from *S. strobiloides*, which may be due to the better protection offered by the dense pubescence. The larger insects were more numerous than small ones in *S. gnaphaloides*.

The following description of the moth bred from the gall *S. gnaphaloides* has been furnished for publication in this paper by Professor C. H. Fernald:—

Acleris heindelana Fernald n. sp.

Expanse of wings, 15–17 mm. Head, thorax, and fore wings dull steel gray, the wings with a trace of light brown stain below the large triangular dark brown costal spot which extends from the basal third to near the outer fifth of the costa and about halfway across the wing. This spot has minute scattered tufts of blackish scales over the surface and there are also a few other blackish scale tufts in places common to the species of this genus.

Fringes concolorous with the adjoining surface of the wing. Hind wings pale gray with a silky luster, a little darker at the apex, and with the fringes of the same color as the base of the wings. Under side of the fore wings much darker than the hind wings and with the costa marked alternately with light and dark gray. The hind wings are sprinkled with brown dots towards the apex. Abdomen of the same color as the hind wings.

Described from two female specimens: one from Lake Forest, Ill., and one belonging to the U. S. National Museum and taken in Winnipeg, Manitoba, by A. W. Hanham.

I have one specimen in rather poor condition which may possibly belong to this species. It is labeled as follows: "Ft. Klamath, Ore., 10.6. '86. T. C. M. Coll."

Eggs of the meadow grasshopper (*Xiphidium ensiferum*) were found in both old and recent galls. In many cases they were dried up. The grasshoppers began to appear in May. Wheeler says that the meadow grasshoppers seem to prefer the blackened and weatherbeaten galls, probably because their scales are more easily forced apart. He believes that this insect's habit of putting its eggs in the galls is of comparatively recent acquisition because in some cases the eggs are poorly placed and because the insect still uses galls whose scales are so close together as to flatten and kill the eggs, evidence that the grasshopper has not learned to distinguish the kind of gall best adapted to its purpose. If we accept Wheeler's conclusion, we may say that the gall is of increasing importance to the insect world.

So far as is known, Tetrastichus is hyperparasitic. There are numerous undescribed species which are difficult to separate.

Polygnotus salicicola was bred from a Cecidomyiid leaf gall of the willow by Mr. A. Koebele at Los Angeles, Cal.

Mr. Theo. Pergande says that both of the thrips, Megalothrips and Phlœothrips, are apparently undescribed.

Ischnorhynchus resedæ Panzer is a common European species, also common in the United States. *Triphleps insidiosus* Say is a common and widespread species found upon berries and upon the ox-eye daisy.

Although it is difficult and often impossible to identify the various insects in their larval state, still an early examination is of value for showing the abundance of life in the individual galls. Usually the larva of the gall gnat which is the maker of the gall,

is present in its central cell. It is easily recognized, not only by its larger size, but especially by the presence of the "breast bone" so characteristic of all Cecidomyiid larvæ. Larvæ of small Cecidomyidæ are found in considerable numbers between the outer scales of many galls. These are also recognized by the "breast bone" but with greater difficulty because of their smaller size.

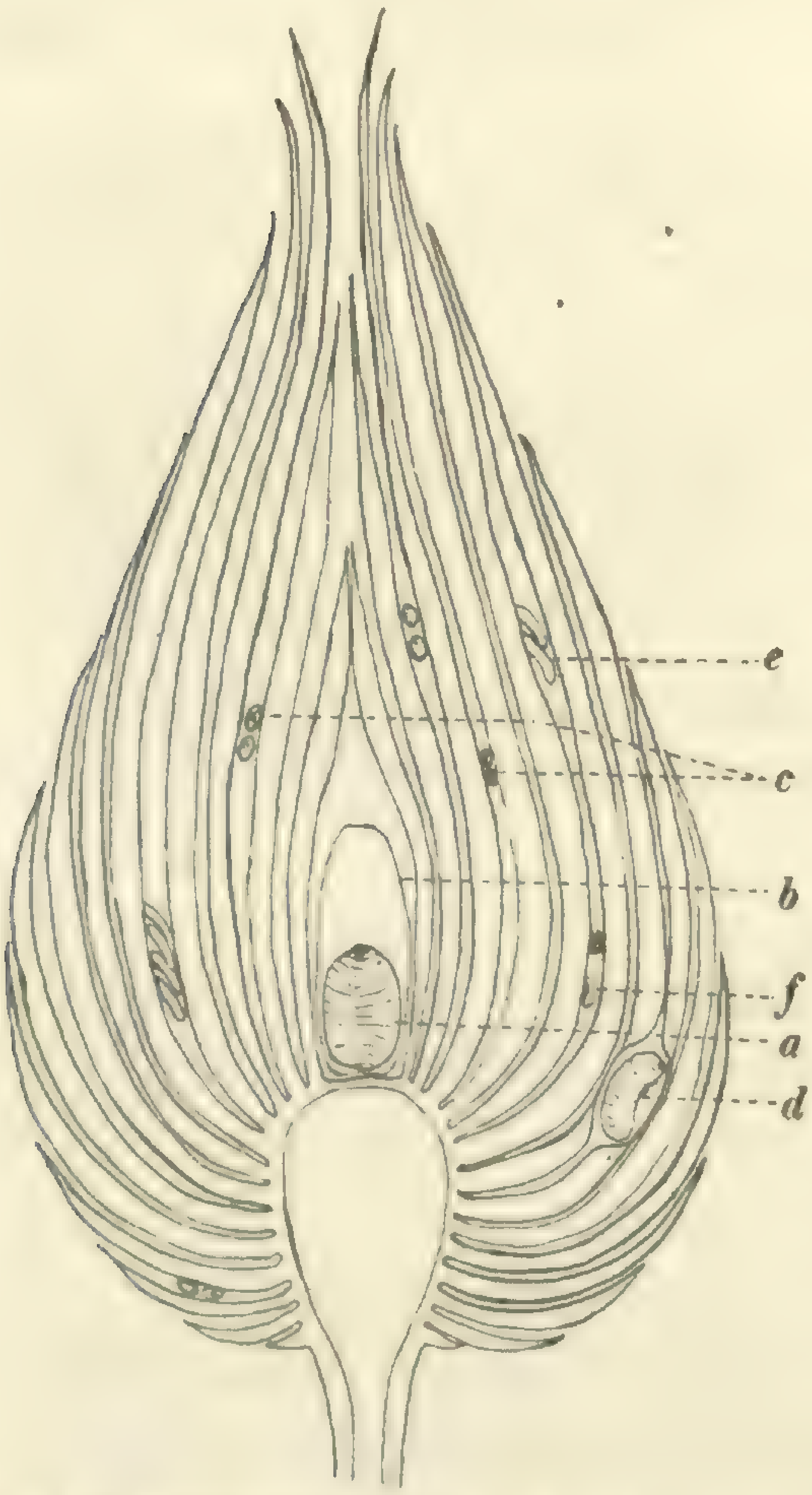

FIG. 5.— Diagrammatic drawing of section of a cone gall, showing positions of gall makers and others. *a*, Rhabdophaga larva; *b*, its cocoon; *c*, guest Cecidomyiid larvæ; *d*, saw fly or moth larva in a burrow; *e*, eggs of *Xiphidium ensiferum*; *f*, larva of Hymenopterous parasite.

Twenty-three 1904 pubescent galls from the region of Pettibone Creek, north of Lake Bluff, Ill., gathered and examined in October, 1904, contained fifteen living and two dead larvæ of the gall gnat which produces the gall (6 galls were without Rhabdophaga larvæ), 169 small Cecidomyiid guest larvæ, 6 larvæ of Hymenopterous parasites of which two were in the central cell of one gall in place of the Rhabdophaga larva, and 384 meadow grasshopper eggs. One 1903 gall from the same place contained 16 grasshopper eggs.

Nine 1904 pubescent galls from South Wayne, Wis., gathered December 26, 1904, contained 9 larvæ of gall gnats, 1 guest Cecidomyiid about half as long as the gall maker, 37 smaller Cecidomyiid larvæ, 2 parasitic larvæ, and 13 grasshopper eggs. Six 1903 galls from same place contained 32 grasshopper eggs.

Seventeen 1904 crooked-stem galls from west of Lake Bluff Ill., gathered January 17, 1905, contained ten larvæ of the gall maker, 28 Cecidomyiid larvæ about half as large as maker, 10

smaller Cecidomyiid larvæ, 5 saw fly larvæ, 13 larvæ of Hymenopterous parasites, and nearly 400 grasshopper eggs. Three 1903 galls from same place contained 3 saw fly larvæ and about 125 grasshopper eggs.

I can conclude with no more appropriate words than those which Walsh used in connection with another gall: "If this one little gall and the insect which produces it were swept out of existence, how the whole world of insects would be convulsed as by an earthquake! How many species would be compelled to resort for food to other sources, thereby grievously disarranging the due balance of insect life! How many would probably perish from off the face of the earth, or be greatly reduced in numbers! Yet to the eye of the common observer this gall is nothing but an unmeaning mass of leaves, of the origin and history of which he knows nothing and cares nothing!"

BIBLIOGRAPHY.

VON BERGENSTAMM, J. E., AND LÖW, P.

'76. Synopsis Cecidomyidarum. *Verh. zoöl.-bot. Gesellsch. Wien*, vol. 26, pp. 1–104.

COOK, M. T.

:03. Preliminary List of Gall-producing Insects Common to Indiana. *Ohio State Naturalist*, vol. 4, pp. 104–106.

OSTEN SACKEN, C. R.

'58. Catalogue of the Described Diptera of North America. *Smithsonian Misc. Coll.*, vol. 3, 112 pp.

SPEISER, P.

:03. Wie die jungen Weidenbäume den Angriff der *Dichelomyia rosaria* H. Lw. unshädlich machen. *Allgem. Zeitschr. f. Entomol.*, vol. 8, pp. 204–206.

WALSH, B. D.

'64. On the Insects, Coleopterous, Hymenopterous, and Dipterous, Inhabiting the Galls of Certain Species of Willow. *Proc. Phila. Entomol. Soc.*, vol. 3, pp. 543–644, vol. 6, pp. 223–288.

WALSH, B. D.

'69. Galls and their Architects. *Amer. Entomol.*, vol. 2, pp. 45–50, 70–74, 103–106.

FORCEST CENTERS OF EASTERN AMERICA.

EDGAR N. TRANSEAU.

An examination into the distribution of the forest trees of eastern North America develops the fact that there are several natural vegetation centers. Adams (: 02) called attention to the

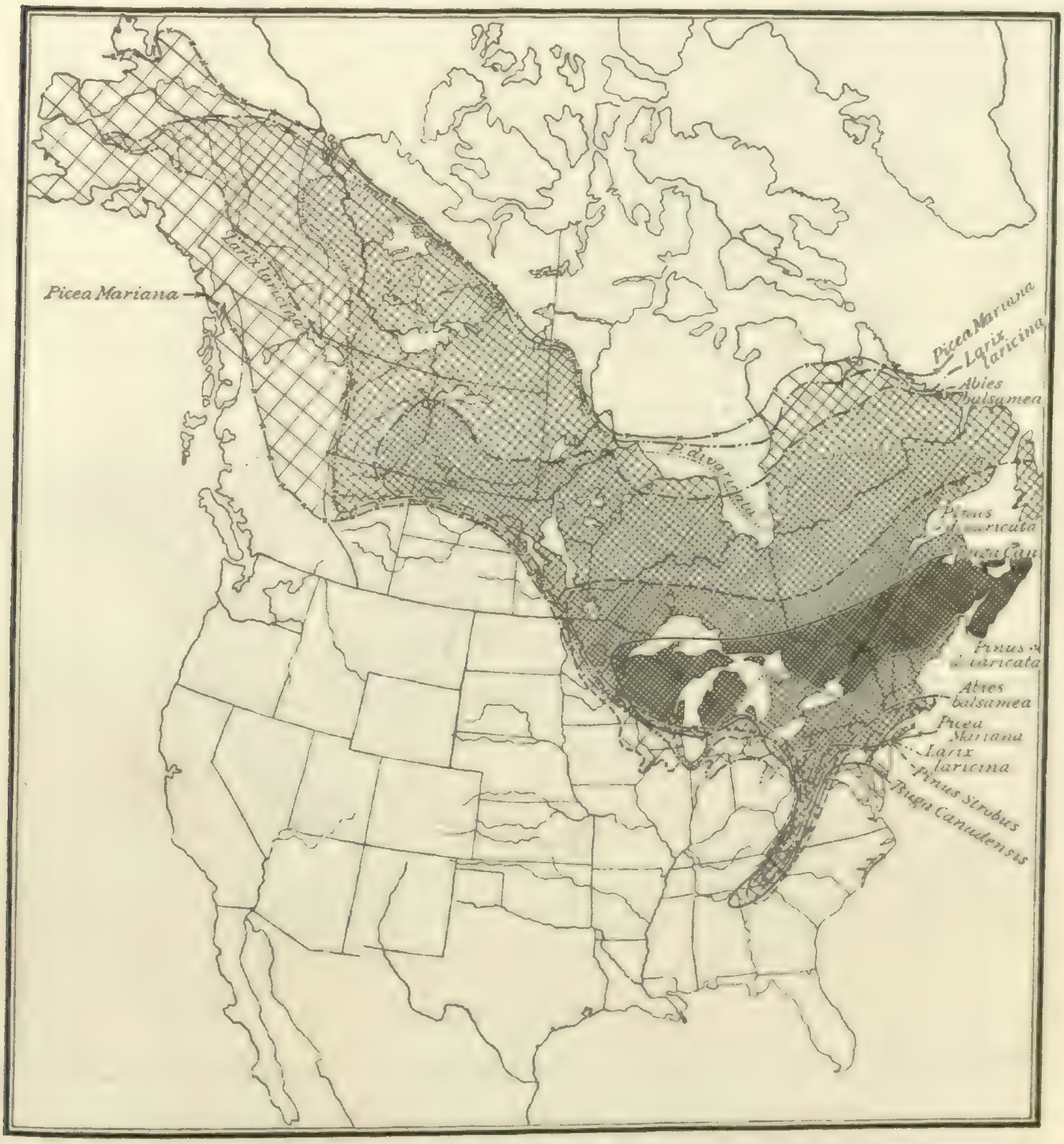

Fig. 1.— Map showing distribution of several of the dominant Conifers of the Northeastern Conifer center. The relative intensity of shading indicates the relative number of species found in the region.

distinctness of the biota of northeastern and of southeastern America, and showed that they are to be regarded as centers of

dispersal for the fauna and flora. In a former paper the writer (:03) pointed out that if the distribution of the characteristic bog plants be plotted on a map, the Laurentian region of Canada is indicated as their center of distribution. Within its limits, the plants have a wider range of habitats, attain a greater size, and are more abundant than elsewhere. It is also shown that

FIG. 2.— Map showing distribution of *Picea canadensis*, *Acer pennsylvanicum*, *Betula papyrifera*, *Prunus pennsylvanica*, and *Betula lutea* about the Northeastern Conifer forest center. The writer is under obligations to Professor Aven Nelson, Dr. P. A. Rydberg, and Mr. W. P. Holt for unpublished data which aided in the construction of this map.

the tree species are most limited in extent of dispersal, the bog shrubs have a wider range, while the herbaceous plants range from the Arctic seas to the Gulf of Mexico.

In using the term "center of distribution" it is not implied that the plants have necessarily spread from these centers, but that the complex of climatic factors most favorable to the development of this type of vegetation is here localized, and that as we depart from such centers we find conditions more and more unfavorable. This implies the elimination of such species as are most rigidly dependent upon definite conditions. Compare for example (Fig. 1) the distribution of *Pinus strobus* and *Tsuga canadensis* with that of *Picea mariana* or *Larix laricina* and note the intermediate dispersal of *Abies balsamea.* Fig. 2 shows the distribution of several other species and still further reinforces the suggestion that the St. Lawrence basin is a definite center about which is distributed a unique type of forest. It is floristically related to the forests of other parts of the continent but ecologically and climatically it is distinct.

The recognition and separation of these centers is of the greatest importance at the present time when there is so much activity along physiographic ecological lines. That there is a natural succession of plant societies in a given locality has long been recognized. Cowles (:01a) has shown that this succession may be correlated with the physiographic development of the region, because soil structure, water content, and slope are largely determined by it. Already the applicability of this hypothesis has been demonstrated in many parts of the United States.

But thus far little attention has been paid to the relation which the successive plant societies found in an area bear to their centers of distribution. In other words, the societies have been studied from their physiographic, but not from their geographic aspect. Such a geographic outlook, however, not only aids in the selection of the characteristic plants of the local habitat, but also throws light on the relative importance of the several societies. The geographic point of view is also necessary to furnish a suitable basis for comparing local meteorological data. Unless the climatic conditions of the centers of distribution of the societies are pointed out, the meaning of local climatic data is not apparent. Further, it is probable that in many areas the societies are not all members of the same geographic center,

so that comparisons with the conditions in two or more centers may be necessary to interpret fully the local data.

The geographic point of view is of the greatest importance in the study of regions intermediate between the great plant formations. In such localities there is a mingling of both species and societies which have spread from very different distribution centers. The local order of succession is usually a mixture of two or more orders, characteristic of as many centers. For example, in northern Michigan the successive societies (Whitford, :01) in the development of the forests, are: (1) xerophilous herbs, (2) the heath, (3) the coniferous forest, and (4) the maple-beech climax forest. While there can be little doubt but that this is the correct interpretation of the forest relationships in this region, there is a notable difference between these societies. The first three may be found anywhere in that region, while the last occurs only in areas favored by a rich soil, the climatic influence of the lakes, and the possibilities of migration from the southeastern deciduous forest. The first three societies are stages in the development of the climax forest of the Northeastern Conifer forest center, the last is the attenuated border of the climax stage of the southeastern Deciduous forest center. The first three stages are largely physiographic, while the last is also geographic, for it marks not only the succession of one society over another, but also the invasion and succession of one forest center over another.

In northern Pennsylvania and part of the mountains of New England, it appears from preliminary work that the successional relationship of the societies can only be traced by taking into account the fact that the societies of northern slopes and certain other edaphic situations are related to the Northeastern Conifer forest and form an order of succession *distinct* from that to which the societies of southern slopes and other favored situations belong.

Where best developed in the lower Ohio basin and Piedmont plateau, the climax stage of the Deciduous forest center (Fig. 3) is made up of many species of which the dominant are *Quercus alba*, *Magnolia acuminata*, *Acer saccharum*, *Fagus americana*, *Liriodendron tulipifera*, *Fraxinus americana*, *Quercus rubra*, and

Hicoria alba. Of these species the most hardy are the beech and the maple. In many places in the northern states the latter occupies areas almost to the exclusion of other trees, while within the southeastern center it is only one of many species in

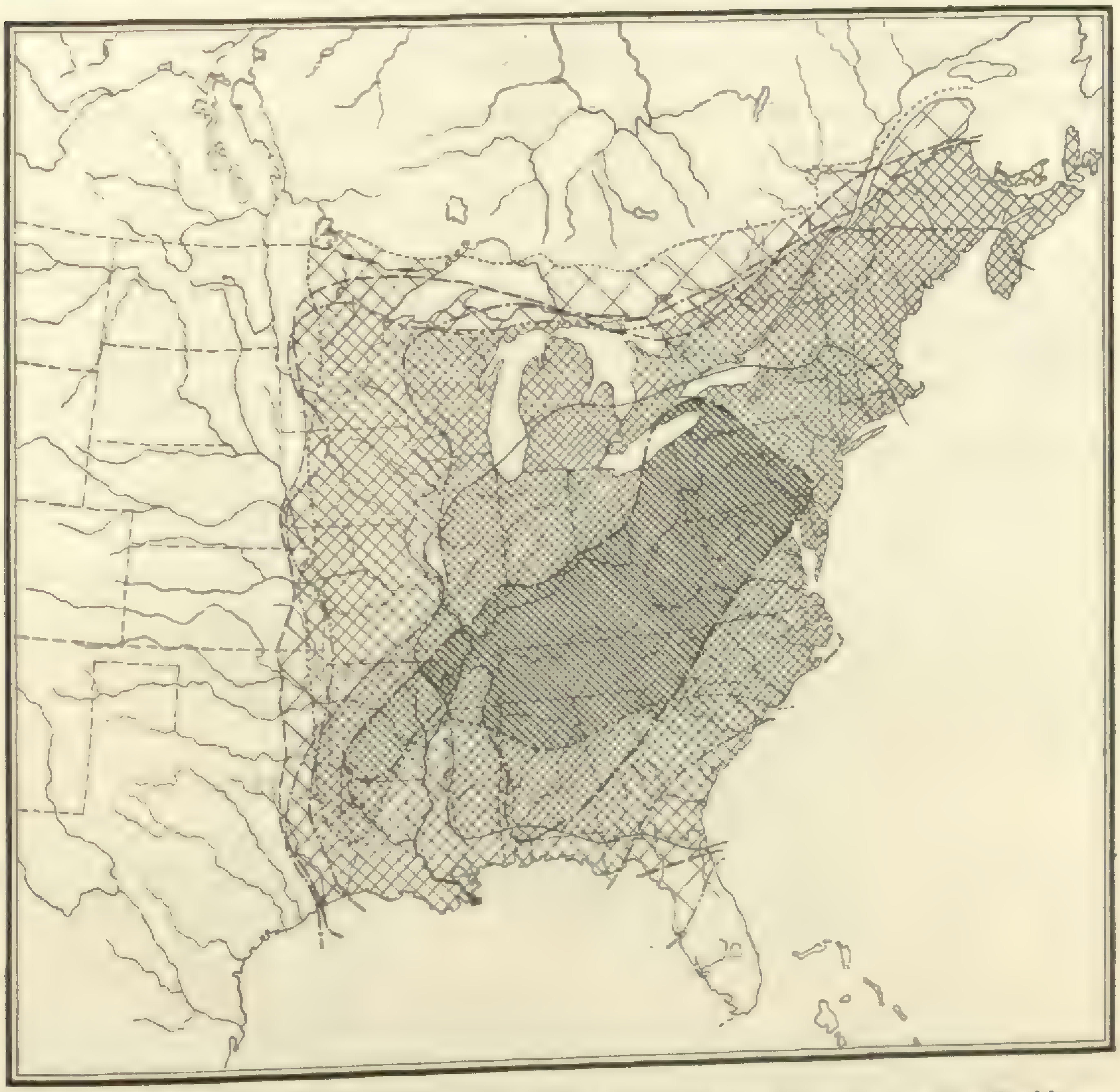

FIG. 3.— Map showing distribution of several trees belonging to the climax stage of the Deciduous forest center. ----, *Acer saccharum*; —— —— ——, *Fraxinus americana*; ——-——-, *Fagus americana*; ——--——--, *Quercus alba*; ————-, *Magnolia acuminata*; ——, *Liriodendron tulipifera*.

the forest. This may be explained, not by the statement that the maple is a northern tree, but by the fact that its shade-enduring and shade-producing properties find no worthy competitor among the trees of the Northeastern Conifer formation, while at the south it is one of many species having the same characteristics.

In the mountain region of the southern Appalachians there is

an extension of the Northeastern Conifer forest. Probably it should be regarded as a subcenter, because of the large number of endemic forms present, and because many other species there attain their greatest development. There, it has been shown (Cowles, :01b) that the pine stage is followed by an oak society, which in turn gives way to the climax deciduous forest. This seems to correspond with the succession in certain parts of the

FIG. 4.— Map showing distribution of several trees belonging to the Southeastern Conifer forest center. *Chamæcyparis thyoides* is a common tree in the coastal swamps; the pines, with the exception of *Pinus glabra*, belong to the climax forest.

lower peninsula of Michigan, where the pines and the oaks both occur. Both localities are intermediate between the same two forest centers, and such a correlation is to be expected. The earlier stages in the succession are dominated by the Northeastern Conifers, while the last two are parts of the Deciduous forest center.

Furthermore in such intermediate regions, we may find two

distinct societies occupying the same or similar habitats. For example, in southern Michigan, the xerophilous bog societies and the hydrophilous swamp societies are so related. The former, however, are a part of the Northeastern Conifer forest, while the latter belong to the Deciduous forest succession. Consequently, where the bog societies are surrounded by oaks they

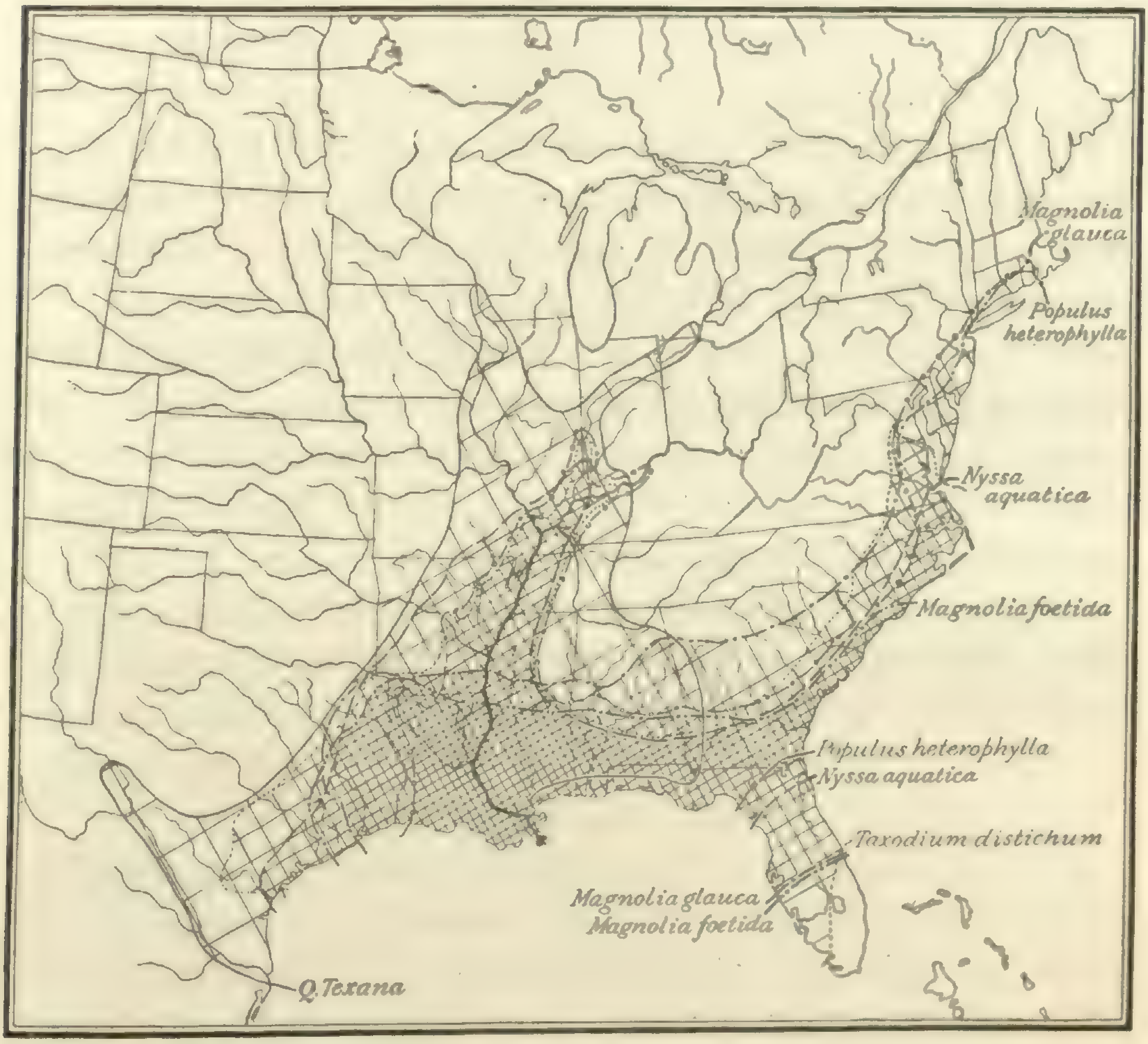

FIG. 5.— Map showing the distribution of some of the swamp trees of the Southeastern Conifer forest center. *Magnolia glauca*, *M. fœtida*, *Nyssa aquatica*, *Populus heterophylla*, *Taxodium distichum*, and *Quercus texana*.

bear no successional relationship, while the swamp societies change gradually into the oak and climax stages of the Deciduous forest. In such cases the geographic considerations are of equal importance with the physiographic, for the proper classification of the plant societies.

Turning to the coastal plain of the southeastern states, we find a dominant forest of Conifers, with mixed Conifer and broad-leafed societies on the low grounds. Here slight differ-

ences of elevation and relative geological age tend to be strongly expressed in the vegetation (Pinchot and Ashe, '97, pp. 143–181; Mohr, :01, pp. 107–133; Harshberger, :04, pp. 611–614). The Conifers probably represent the climax forest of this formation. The distribution of certain of its components is shown in Figs. 4 and 5. Several other associations of shrubs and trees might be similarly depicted and still further emphasize the identity of the Southeastern Conifer forest center. As shown by the accompanying maps and the descriptions of Smith, and Pinchot and Ashe, there is a mingling of societies of this center and of the Deciduous forest, in the region of the Piedmont plateau, which tends to obscure the recognition of the stages properly belonging to each.

On the southern half of the Florida peninsula is a fourth formation, made up largely of xerophilous tropical species. It really represents the northern border of a center which dominates the West Indies and tropical America. It may be designated the Insular Tropical forest center.

There appear then to be four centers of distribution in eastern North America: (1) the Northeastern Conifer, (2) the Deciduous, (3) the Southeastern Conifer, and (4) the Insular Tropical. Each is made up of many societies, which bear a definite successional relationship to one another.

With the exception of the tropical, each of these formations has its western border marked by gradation into the grasslands of the Great Plains. The local flora of any part of the intermediate prairie region is composed of societies from the plains and the adjoining forest centers. For example, take the succession of plant societies on the bluffs of the Kansas River in eastern Kansas. The pioneer society is made up of *Bouteloua hirsuta*, *Mentzelia oligosperma*, *Euphorbia marginata*, *E. dentata*, *E. petaloidea*, *Bœbera papposa*, *Artemisia ludoviciana*, *Aster sericeus*, *A. fendleri*, *Megapterium missouriense*, *Tragia ramosa*, *Baptisia bracteata*, *B. australis*, *Lacinaria punctata*, *Croton texensis*, *Solidago missouriensis*, and *Silphium laciniatum*. This society belongs to the flora of the Great Plains and has its eastern limit in the prairie belt. The shrub stage following this is made up principally of *Symphoricarpos symphoricarpos*, *Ceanothus ovatus*,

Rhus glabra, *R. aromatica*, *R. radicans*, *Cornus asperifolia*, *C. amomum*, and *Xanthoxylum americanum*. This society is of very different origin and represents the western border of the shrub stage of the Deciduous forest formation. The shrubs are succeeded by trees belonging to the same center, among which are *Juniperus virginiana*, *Ostrya virginica*, *Celtis occidentalis*, *Quercus acuminata*, *Cercis canadensis*, *Ulmus fulva*, etc. A very different combination of societies would be met with in similar situations in northwestern Minnesota or southeastern Texas because of the different centers involved.

The mapping of these centers naturally brings up the question of the climatic determinants of each. During glacial times the Northeastern Conifer must have been mixed with the Deciduous forest. Why are they so distinctly separated at the present time? What are the causes of the "prairie peninsula" in Iowa, Illinois, and Indiana; and the region of open forests adjoining it? Naturally we look for some method of mapping climatic data, which will show climatic centers in approximately the same positions as the centers of plant distribution. An examination of monthly, seasonal, and annual temperature and rainfall maps shows that neither of these factors alone can do this. Historical considerations may aid in explaining the relative positions of these centers, but are inadequate for the complete explanation of their present limits.

A method was accordingly sought by which temperature and moisture data could be combined in a single number. The fact that so large a part of all plant adaptations is directly or indirectly connected with transpiration, suggested that if the ratio of the rainfall to the evaporation were determined, a new basis for mapping would be at hand which would involve several climatic factors. The depth of evaporation depends upon (T. Russell, '88) the temperature of the evaporating surface, the relative humidity of the air, and the velocity of the wind. These are the same climatic factors which most powerfully affect transpiration, and which must be of great importance in determining the geographic range of plants. Unfortunately, the only figures for evaporation available are those published by T. Russell for the year beginning July 1, 1887, and extending to July 1, 1888. They

represent the possibilities of evaporation from a free water surface inside the instrument shelters. Just as the figures for the rainfall do not represent the amount of water actually available for plants (since it includes the run-off, the part that evaporates, and that which sinks into the ground) so the figures for evaporation do not correspond to the water vapor actually given off by plants, because this is determined largely by the ecological adaptations of the individual plants. But the figures have a comparative value in both cases and when combined probably give a fairly correct idea of the distribution of these climatic factors in the eastern United States. The map was not extended to the western states owing to the paucity of data and the disturbing influence of the mountains. However, sufficient evidence is at hand to show that a desert center is clearly indicated in southern Arizona and California, and a forest center in the Puget Sound region. A comparison of the data for Colorado Springs and Pike's Peak indicates that the ratio increases from about 20 percent to 100 percent as one goes from the base to the summit of the Peak. This suggests the importance of taking other factors than temperature into account when explaining the distribution of the forests on mountains.

Turning now to the map (Fig. 6) showing the distribution of the rainfall-evaporation ratios in the eastern states, it will be noted that the Great Plains are marked by a rainfall equal to from 20 to 60 percent of the evaporation called for. The prairie region where forests are confined to the low grounds, is indicated by a ratio of from 60 to 80 percent. Its limits as indicated show a remarkable agreement with the actual distribution of the prairie. The region indicated by ratios between 80 and 100 percent is more or less coincident with the occurrence of "oak openings," "open forests," and "groves" on the uplands, and dense forests on the low grounds.

The southeastern area where the rainfall is from 100 to 110 percent of the evaporation, corresponds to the region of the Deciduous forest center. The distribution of the ratios above 110 percent in the region of the coastal plain is remarkably similar to the position of the Southeastern Conifer forest center.

In the southern Appalachians the ratio also rises above 110 percent and coincides with the occurrence of the southern extension of the northeastern forests. No data are available for the mountainous parts of Pennsylvania, so that this apparently isolated area may be climatically connected northward along the

FIG. 6.— Map showing ratio of rainfall to evaporation expressed in percentages. (Compare with Sargent's map of the "Forests of North America," *10th Census Report*.)

higher mountain crests. The Northeastern Conifer forest center is marked by ratios above 100 percent and centering in the St. Lawrence basin. It is probable that the northern limits of this formation will not be indicated by the rainfall-evaporation ratios, for the factors commonly accepted (Schimper, :03, p. 168) as determining the northern limits of forests are very different from those causing the boundaries of other formations. It should

also be stated that since climates are constantly changing and effects may lag far behind their causes, no map of present climatic conditions can hope to do more than approximate the present distribution of plants. Geographic and historical relations must be constantly borne in mind.

SUMMARY.

It may be stated, by way of summary, that eastern North America is occupied by four great forest centers: (1) the Northeastern Conifer forest, centering in the St. Lawrence basin, (2) the Deciduous forest, centering in the lower Ohio basin and Piedmont plateau, (3) the Southeastern Conifer forest, centering in the south Atlantic and Gulf coastal plain, and (4) the Insular Tropical forest of the southern part of the Florida peninsula, centering in the West Indies. The term center as here used, implies the idea of distribution about a region where the plants attain their best development. Such vegetation divisions are not fixed, but move and increase or decrease in extent depending upon continental evolution and climatic change.

Each formation is made up of many societies, bearing a definite successional relationship to one another, which being dependent upon soil factors may be best correlated with physiographic changes. In regions intermediate between centers, the local order of succession is made up of societies from each of the adjoining formations.

It has been found that if the ratios produced by dividing the amount of rainfall by the depth of evaporation for the same station, be plotted on a map they exhibit climatic centers which correspond in general with the centers of plant distribution. Further, the distribution of grassland, prairie, open forest, and dense forest regions is clearly indicated.

This is explained by the fact that such ratios involve four climatic factors which are of the greatest importance to plant life, *viz.*, temperature, relative humidity, wind velocity, and rainfall.

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BIBLIOGRAPHY.

Adams, C. C.

:**02**. The Southeastern United States as a Center of Geographical Distribution of Flora and Fauna. *Biol. Bull.*, vol. 3, no. 3, p. 115.

Adams, C. C.

:**05**. The Postglacial Dispersal of the North American Biota. Read at the 8th International Geographic Congress. *Biol. Bull.*, vol. 9, p. 53.

Beal, W. J.

:**04**. Michigan Flora. *5th Ann. Rep. Mich. Acad. Sci.*, 147 pp.

Bessey, C. E.

'**99**. The Forests and Forest Trees of Nebraska. *Ann. Rep. Neb. State Bd. Agric.*, p. 79.

Bishop, J. N.

:**01**. Catalogue of Phænogamous and Vascular Cryptogamous Plants of Connecticut. *35th Ann. Rep. of Sec'y Conn. Bd. Agric.*

Britton, N. L.

:**01**. Manual of the Flora of the Northern United States. Henry Holt & Co., New York.

Clark, A. M.

'**99**. The Trees of Vermont. *Contributions to the Botany of Vermont, V., Bot. Dept. Univ. Vt.*

Coulter, S.

'**99**. Catalogue of the Flowering Plants and Ferns of Indiana. *24th Ann. Rept. Dept. Geol. Ind.*, p. 553.

Cowles, H. C.

:**01a**. Physiographic Ecology of Chicago and Vicinity. *Bot. Gaz.*, vol. 31, p. 145.

Cowles, H. C.

:**01b**. Influence of Underlying Rocks on the Character of the Vegetation. *Bull. Amer. Bur. Geog.*, vol. 2.

Harshberger, J. W.

:**04**. The Comparative Age of the Different Floristic Elements of Eastern North America. *Proc. Acad. Nat. Sci. Phila.*, 1904, p. 601.

Harvey, L. H.

:**03**. A Study of the Physiographic Ecology of Mt. Ktaadn, Me. *Univ. of Me. Studies*, no. 5.

Hinckley, F. C.

'**99**. Notes on the Animal and Vegetable Life of the Region of the

Sushitna and Kuskokwim Rivers, Alaska. *20th Ann. Rep. U. S. Geol. Surv.*, vol. 7, p. 77.

Kearney, T. H.

:00. The Lower Austral Element in the Flora of the Southern Appalachian Region. *Science*, n. s., vol. 12, p. 830.

Kellerman, W. A.

'99. The Fourth State Catalogue of Ohio Plants. *Ohio State Univ. Bull.*, ser. 4, no. 10.

Kimball, H. H.

:05. Evaporation Observations in the United States. *U. S. Weather Bur. Bull.*, no. 327.

Livingston, B. E.

:03. The Distribution of the Upland Plant Societies of Kent Co., Michigan. *Bot. Gaz.*, vol. 35, p. 36.

Macoun, J.

'83. Catalogue of Canadian Plants. Pts. 1 to 3. *Geol. and Nat. Hist. Surv. Canada.*

Macoun, J. M.

'95. Contributions from the Herbarium of the Geological Survey of Canada. *Can. Rec. Sci.*, vol. 6, Apr.

Mason, S. C.

'92. Preliminary Report upon the Variety and Distribution of Kansas Trees. *8th Ann. Rep. Kans. State Bd. Agric.*

Mendenhall, W. C.

:02. Reconnaissance from Fort Hamlin to Kotzebue Sound, Alaska. *Prof. Paper, U. S. Geol. Surv.*, no. 10, p. 58.

Merriam, C. H.

'91. Distribution of Life in North America, with Special Reference to the Mammalia. *Smithson. Rep.*, 1891, p. 365.

Mohr, C.

'97. Timber Pines of the Southern United States. *Div. of Forestry, U. S. Dept. Agric.*, bull. 13.

Mohr, C.

:01. Plant Life of Alabama. *Geol. Surv. of Ala.*

Pinchot, G., and Ashe, W. W.

'97. Timber Trees and Forests of North Carolina. *N. C. Geol. Surv.*, bull. 6.

Porter, T. C.

:03. Flora of Pennsylvania. Ginn & Co., Boston.

Russell, T.

'88. Evaporation. *Monthly Weather Review*, Sept.

Rydberg, P. A.

'96. Flora of the Black Hills of South Dakota. *Contrib. U. S. Nat. Herb.*, vol. 3, no. 8.

Sargent, C. S.

'84. Forests of North America. *10th Census of the U. S.*, vol. 9.

SARGENT, C. S.
'91–:02. The Silva of North America. Houghton, Mifflin & Co., Boston.

SARGENT, C. S.
:05. Manual of the Trees of North America. Houghton, Mifflin & Co., Boston.

SAUNDERS, D. A.
'99. Ferns and Flowering Plants of South Dakota. *S. Dak. Agric. Exper. Sta.*, bull. 64.

SCHIMPER, A. F. W.
:03. Plant Geography upon a Physiological Basis. Translation by W. R. Fisher, Oxford.

SMALL, J. K.
:03. Flora of the Southeastern United States. Pub. by the author, New York.

SUDWORTH, G. B.
'98. Checklist of the Forest Trees of the United States. *Div. of Forestry, U. S. Dept. Agric.*, bull. 17.

TRANSEAU, E. N.
:03. On the Geographical Distribution and Ecological Relations of the Bog-plant Societies of Northern North America. *Bot. Gaz.*, vol. 36, p. 401.

VASEY, G.
'84. The Distribution of North American Forest Trees. *U. S. Dept. of Agric.*, spec. rep. no. 5, p. 38.

WEATHER BUREAU, U. S.
:04. The Record of Weather in the United States. *The American Almanac*, p. 77.

WHITFORD, H. N.
:01. The Genetic Development of the Forests of Northern Michigan. *Bot. Gaz.*, vol. 31, p. 315.

MANDIBULAR AND PHARYNGEAL MUSCLES OF ACANTHIAS AND RAIA.[1]

GUY ELLWOOD MARION.

Introduction.

The following paper deals only with the muscles of the jaw and branchial region in the common dogfish (*Acanthias vulgaris*), and in one of the common skates (*Raia erinacea*). The existing literature upon this subject is very scanty, and aside from a few scattered references to the muscles, I have found only the detailed papers by Vetter ('74) upon the mandibular and branchial regions of the sharks, and a similar paper by Tiesing ('95) who discusses in the same way the muscles of the skates. Drüner (:03) uses the Selachians in describing the visceral muscles of the Urodeles.

The present article follows very closely the work of Vetter and Tiesing, especially that of the former. Tiesing classifies and arranges the muscles upon the basis of innervation; Vetter upon that of position and function. That the former method has its advantages is admitted, but convenience leads me to adopt the scheme of Vetter; and although not agreeing with him in all points, I have adopted as far as possible his nomenclature and lettering of the figures. As was said above, Vetter deals only with the sharks, and Tiesing with the skates, while I have tried to draw homologies between the two groups, and this has led me at times to differ from my predecessors.

The mandibular and branchial muscles may be divided into four main groups: —

1. Superficial circular muscles.
2. Interarcuales (muscles between the upper ends of the branchial arches).
3. Adductores (flexors at the middle of the arches).

[1] Contributions from the Biological Laboratories of Tufts College, No. XLIII.

4. Ventral longitudinal muscles.

Each of these in turn contains several muscles which are capable of arrangement under subordinate headings. In the following account, the muscles of one of the major divisions will be described for Acanthias, and then the corresponding muscles for Raia.

Superficial Circular Muscles.

Of these there are seven groups :—

1. Superficial constrictors ; *a*, dorsal ; *b*, ventral.
2. Interbranchiales (lying between the walls of the gill clefts).
3. Levator maxillæ superioris (raising the upper jaw).
4. Trapezius (raising the shoulder girdle and drawing it forward).
5. Levator labialis superioris (raises the upper lip).
6. Levator rostri (raises the rostrum). In Raia only.
7. Depressor rostri (depresses the rostrum). In Raia only.

Superficial Constrictors.

Acanthias.

The superficial constrictors are the most external of the muscles which cover the gill pouches and form the surface of the region of the 'neck.' They may be divided, from position, into dorsal and ventral constrictors and are six in number on either side. Between them the five gill slits are placed, the first lying between the second and third, the fifth gill slit occurring behind the sixth constrictor (Figs. 1, 2). The gill slits are slit-like in character, about 18 mm. in extent, and are vertical in position, located near the ventral portion of the side of the body.

Dorsal Constrictors.— The first and most anterior dorsal constrictor (Fig. 2, *Csd 1*) takes its origin from the lateral surface of the cranium just below the posterior end of the dorso-lateral ridge. Its point of origin is not separated from that of the levator maxillæ superioris, to be described below. Its fibers run ventrally and forward, curving around the anterior wall of the

spiracle in front of the spiracular cartilages, and are inserted upon the inner surface of the lower jaw just below the 'coro-

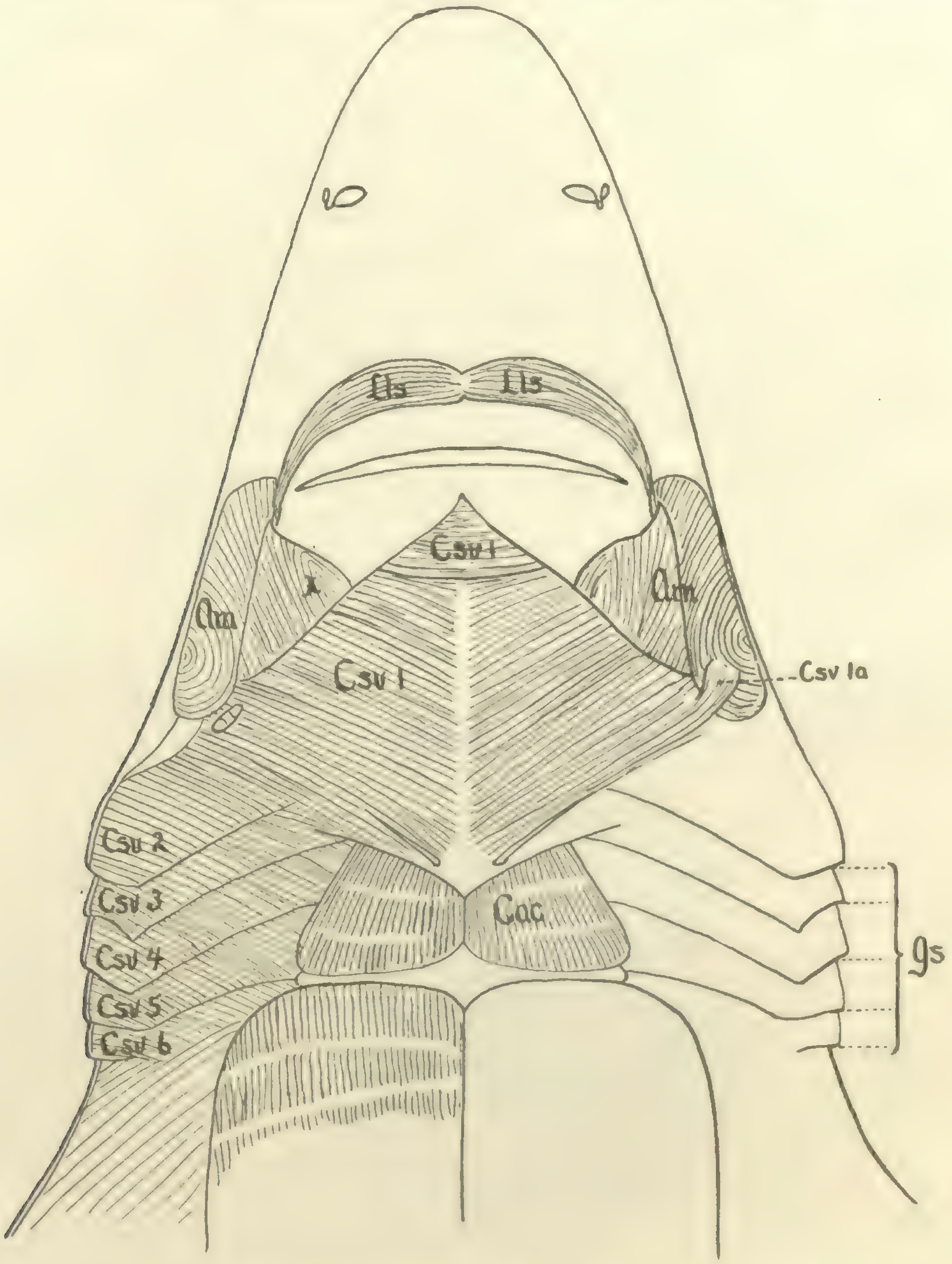

FIG. 1.—Ventral muscles of Acanthias after removal of skin. *Am*, adductor mandibularis; *Cac*, coraco-arcualis communis; *Csv 1-6*, constrictores superiores ventrales; *Csv 1a*, constrictor superioris ventralis, anterior fibers; *Gs*, gill slits; *Lls*, levator labialis superioris; *x*, tendon in adductor mandibularis.

noid' process. The general course of the fibers is curved, while that of the levator maxillæ superioris is straight, the only

feature distinguishing these two muscles, which Vetter does not regard as separate. I believe that of this common mass of muscles the anterior straight fibers alone represent the true levator maxillæ superioris, while the posterior curved fibers represent a

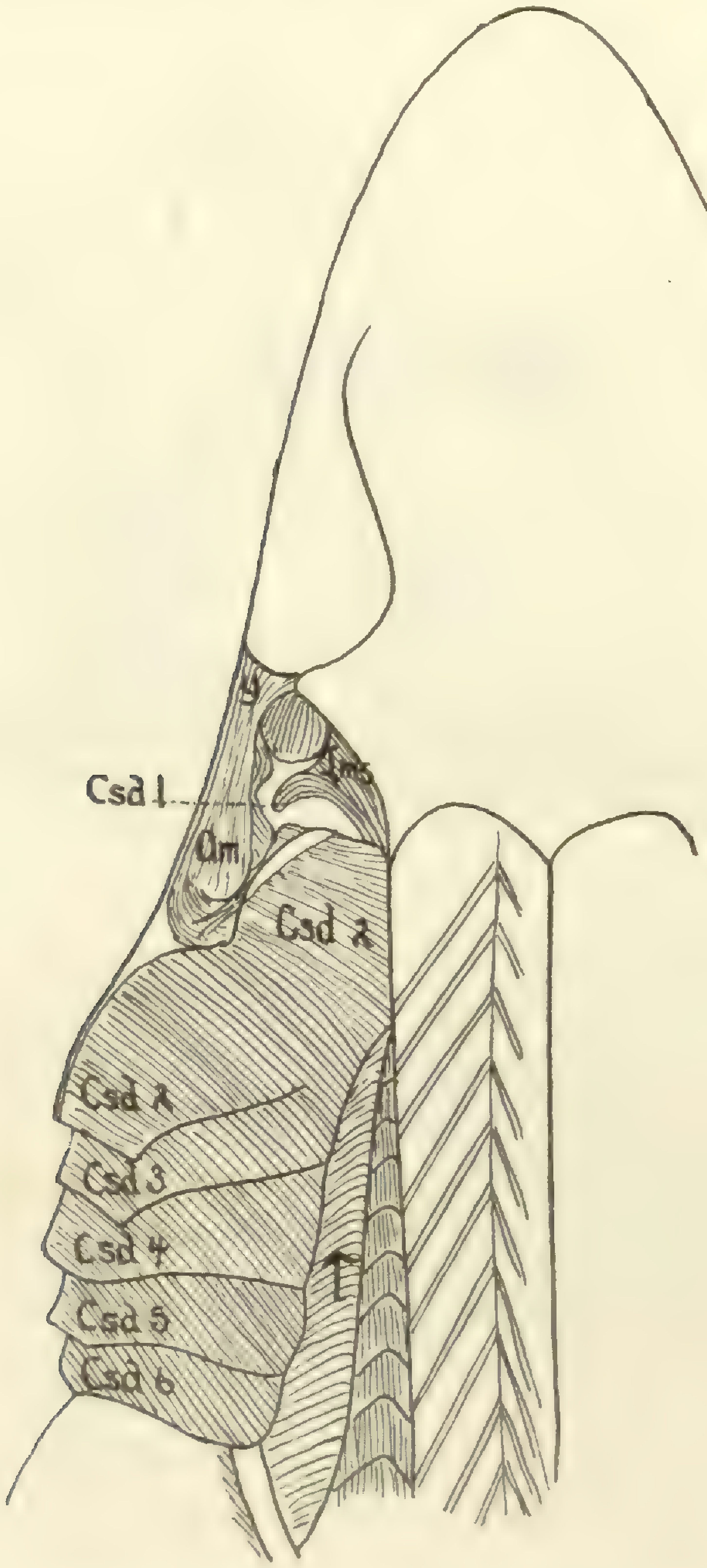

FIG. 2.— Dorsal muscles of Acanthias after removal of the skin. *Am*, adductor mandibularis; *Csd 1–6*, constrictores superiores dorsales; *Lms*, levator maxillæ superioris; *y*, tendinous mass back of eye; *T*, trapezius.

dorsal constrictor. In this connection Vetter ('74, pp. 420–421) says: "Die beiden Spritzlochknorpeln, welche fast senkrecht

zum Faserverlauf dieser Partie nach aussen gerichtet sind, lagern sich dabei ihrer hintern Fläche dicht an, so dass diese zu den Spritzlochknorpeln genau in dieselber Beziehung tritt, wie sie zwischen den Mm. interbranch. und den knorpeligen Radien des Kiemenbogen, oder zwischen *Csd 2* und *Csv 2* und den Radien des Zungenbeinbogen besteht."

Vetter has not carried his comparisons far enough. If these fibers nearest the spiracular cartilages bear the same relation to these cartilages as do those of the second dorsal and ventral constrictors to the rays of the hyoid arch, then why do they not represent another constrictor muscle *Csd 1* exactly like *Csd 2* in general relations? By a further comparison with Raia (Fig. 6) we see that the general course of the fibers of the posterior part as well as the insertion make this part distinctly comparable to the *Csd 1* of that form.

The second dorsal constrictor (Fig. 2, *Csd 2*) is by far the largest of the dorsal constrictors. It is a wide flat muscle extending from just behind the spiracle to the first gill slit. In front it arises from the postero-lateral surface of the cranium, farther back from the strongly fibrous fascia which completely covers the dorsal muscles. This origin extends as far back as the anterior end of the trapezius (Fig. 11) and even beyond that the fibers send tendinous attachments through the trapezius to their origin in the main tendinous fascia covering the longitudinal muscles. The first dorsal aponeurosis between the constrictors runs from the point where the fibers enter the trapezius in an obliquely ventral direction to the dorsal end of the first gill cleft. From this aponeurosis the more posterior fibers of *Csd 2* take their origin. The fibers of the muscles run obliquely from their origin on the dorsal margin of the muscle.

The insertion is also diverse. The most anterior fibers, which bound the spiracle behind, are inserted at the quadrate end of the upper jaw. The next fibers run around and cover the hyomandibula and are inserted upon the ceratohyal cartilage. This portion of the muscle corresponds to the levator hyomandibularis of Raia, where, attached to the same visceral arch, it has become much further developed. Beyond this portion the fibers are inserted upon a tendinous bridge connecting the dorsal and ven-

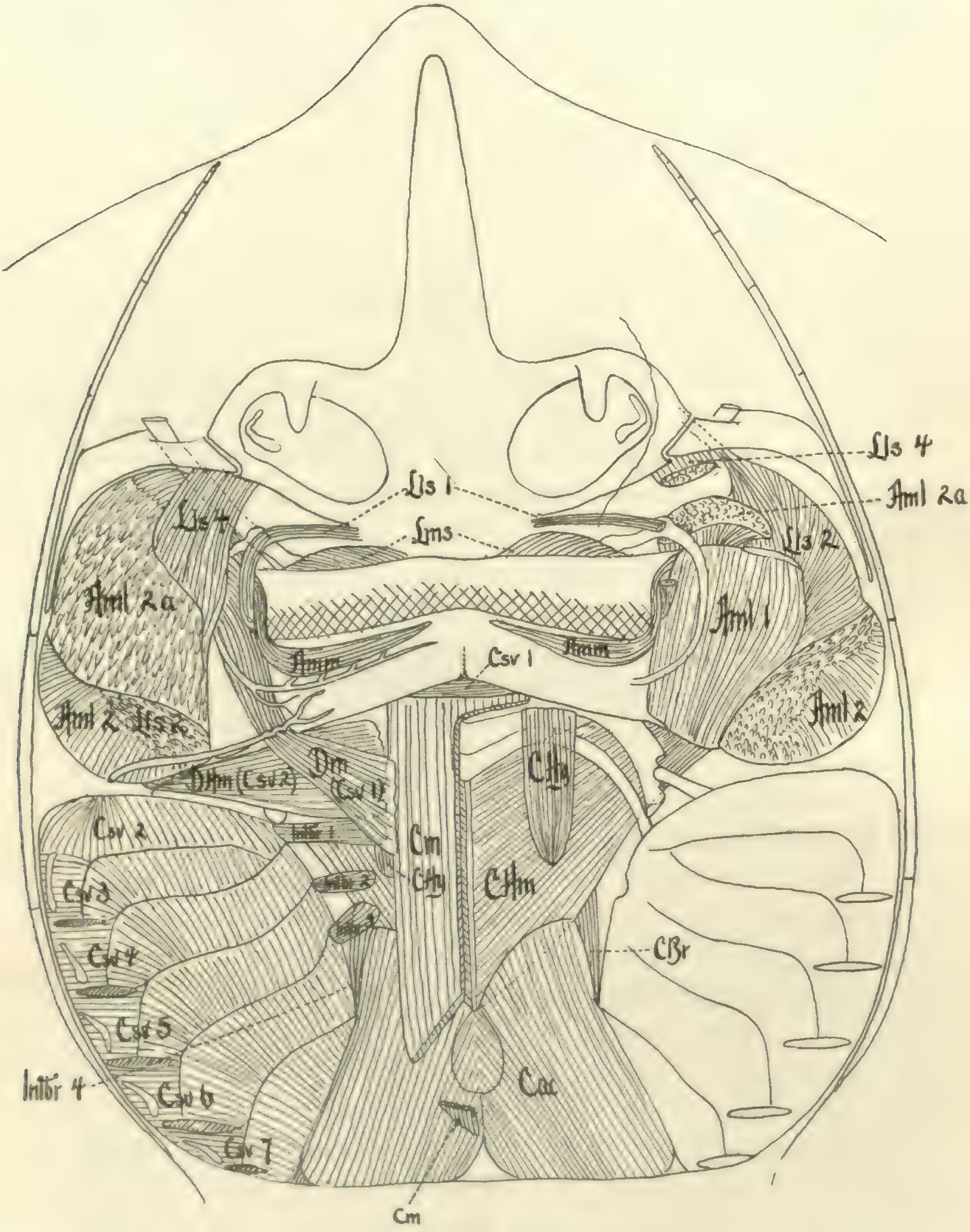

FIG. 3. — Ventral view of Raia, the right half a deeper dissection than the left. *Aml 1, 2*, adductores mandibularis lateralis (superficial layer, posterior); *Aml 2a*, adductor mandibularis lateralis (superficial layer anterior); *Amm*, adductor mandibularis medialis; *Cac*, coraco-arcualis communis; *CBr*, coraco-branchialis; *CHm*, coraco-hyomandibularis; *CHy*, coraco-hyoideus; *Cm*, coraco-mandibularis; *Csv 1-7*, constrictores superiores ventrales; *DHm*, depressor hyomandibularis; *Dm*, depressor mandibularis; *Intbr 1-4*, interbranchiales; *Lls 1-4*, levatores labialis superioris; *Lms*, levator maxillæ superioris.

tral constrictors. This bridge extends about halfway from the end of the hyoid arch to the first gill slit. The remaining fibers pass over into those of the ventral constrictors, forming a continuous muscle. The fibers follow the direction of the gill slit in their course.

The remaining dorsal constrictors (three to six) are so closely similar that one description will serve for all (Fig. 2). The tendinous aponeuroses between them are somewhat curved, each ending at the top of a gill cleft and covering an underlying extrabranchial cartilage. The muscle fibers run nearly vertically and those attached to the aponeuroses are often also attached to the extrabranchials. Towards the dorsal margin some of the fibers converge to a tendon at the posterior edge of the muscle, and these tendons, after piercing the trapezius (Fig. 11, *Csd* 2–6), have their points of origin among the fibers of the dorsal longitudinal muscles, the last being also attached to the shoulder girdle. The more ventral fibers arise from the aponeurosis behind each muscle and are in part inserted on the aponeurosis in front, and in part continuous with the fibers of the ventral constrictors.

Ventral Constrictors. — The ventral constrictors (*Csv*) do not differ markedly from the dorsals, and like them are six in number. Here I am at variance with Vetter ('74, p. 416) who does not describe a first ventral constrictor for Acanthias, but begins with *Csv* 2. This is, however, clearly the first ventral constrictor, while his *Csv β 2* is really the *Csv 2*, for if we compare ventral with dorsal sides, we find that the muscle in front of the spiracle which is inserted on the upper jaw is, as Raia shows, the first, while that upon the hyoid is the second dorsal constrictor. Just so, upon the ventral side the muscle attached to the lower jaw should be designated *Csv 1*, that upon the hyoid, *Csv 2*. With this exception my account of the ventral constrictors agrees well with that of Vetter.

On removing the skin and dissecting away the large amount of connective tissue upon the ventral side of the body (Fig. 1), we find immediately in front of the pectoral girdle, a pair of muscles, the coraco-arcuales communes (*Cac*) which, running forward, soon disappear under large sheets of muscle (*Csv 1, 2*)

which have their origin from a median line of aponeurosis and run obliquely forward and laterally to the cartilage of the lower jaw. This median aponeurosis starts at the level of the first gill slit, about half an inch in front of the pectoral girdle, and

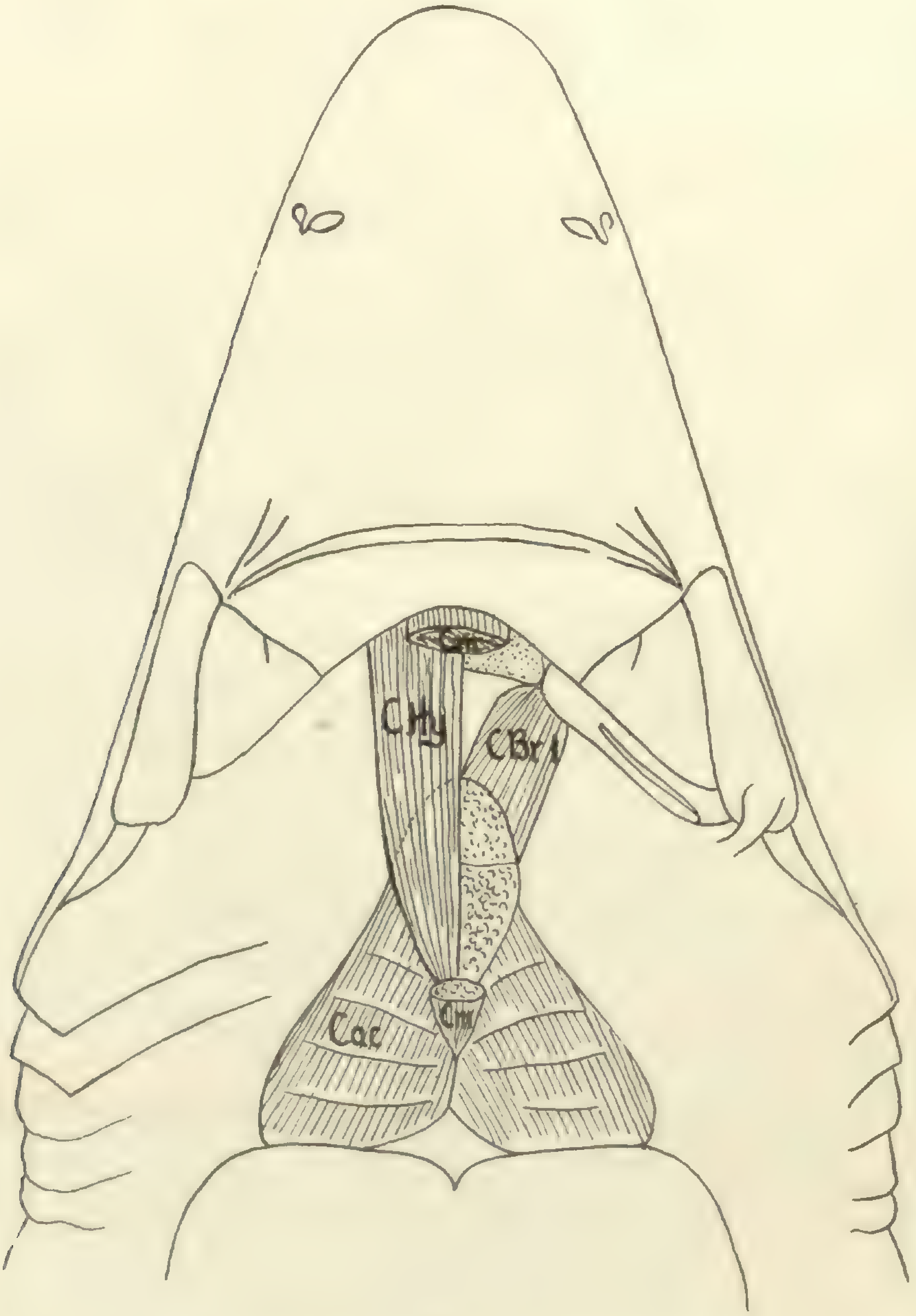

FIG. 4.— Ventral view of Acanthias showing the ventral longitudinal muscles. The right half a deeper dissection than the left. *Cac*, coraco-arcualis communis; *CBr 1*, coraco-branchialis; *CHy*, coraco-hyoideus; *Cm*, coraco-mandibularis.

extends to within half an inch of the symphysis of the lower jaw. The other ventral constrictors (*Csv* 2–6) are visible at either side of the coraco-arcuales communes.

The first ventral constrictor (Fig. 5, *Csv 1*) arises from the

median aponeurosis in common with, but ventral to, the second (*Csv* 2). Its fibers run obliquely forward and are inserted by means of small tendinous portions upon the ventral edge of the lower jaw. A few of the more posterior fibers (*Csv 1a*) are

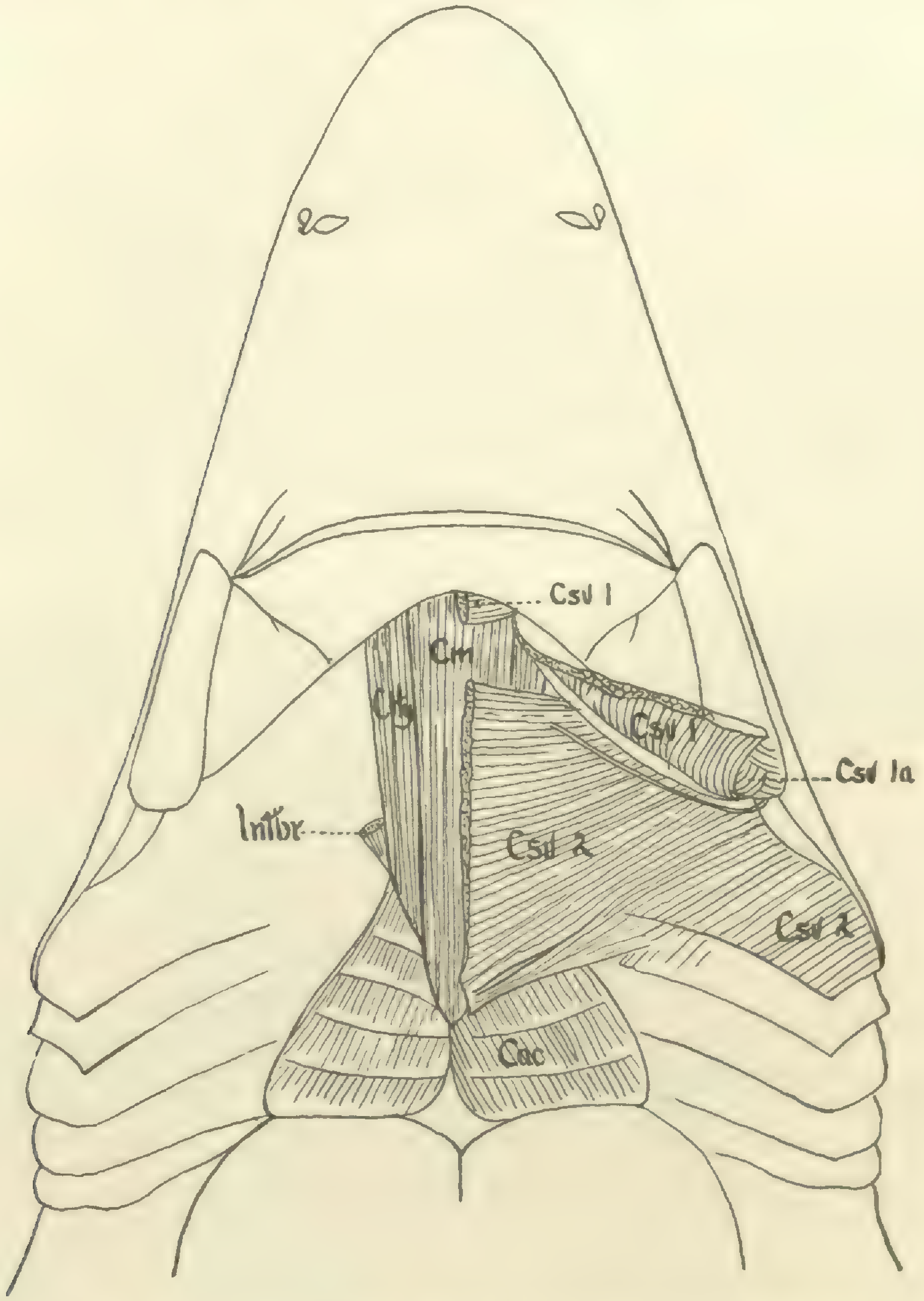

Fig. 5.— A deeper dissection of Acanthias. On the right, *Csv 1* has been turned back to show the whole of *Csv 2*. *Cac*, coraco-arcualis communis; *CHy*, coraco-hyoideus; *Cm*, coraco-mandibularis; *Csv 1–2*, constrictores superiores ventrales: *Csv 1a*, constrictor superioris ventralis, anterior fibers; *Intbr*, interbranchiales.

inserted upon the adductor of the lower jaw instead of upon the Meckelian cartilage, and here the fibers of *Csv 1* and *Csv 2* become fused so that at this point there is no sharply defined

margin to the first constrictor. In front the fibers of this muscle are not separated by a median aponeurosis, but run from one half of the jaw to the other.

Like the second dorsal, the second ventral constrictor (Fig. 5, *Csv 2*) is much the largest of the series. It does not extend as far forward as *Csv 1*, but, on the other hand, it extends back to the first gill cleft. About half of its fibers arise from the median aponeurosis, run parallel with those of the first ventral constrictor, and are inserted on the ventral edge of the ceratohyal cartilage. The posterior fibers, on the other hand, have their origin in the aponeurosis separating the second and third ventral constrictors, and, as they become too posterior to find attachment to the lower jaw or to the ceratohyal, they are inserted upon the fibrous bridge mentioned in connection with the second dorsal constrictor (p. 895), while still farther back the fibers run over into those of the first dorsal constrictor, passing in front of the first gill slit and running parallel to its margin.

The remaining ventral constrictors (*Csv 3–Csv 6*) are closely similar to each other, the only difference being in the points of origin. Excepting 3 and 6, the origin is either in the aponeurosis between each and the next succeeding muscle, or, in the case of the median fibers, from the fascia between the gill cavities and the common coracoid muscles. The most medial fibers of the second muscle take their origin, like those of *Csv 2*, in the median line ventral to the common coracoids, while the sixth has its origin in the pectoral girdle and in the fascia covering the ventral fin-muscles. The fibers of all of these muscles are either inserted in the aponeurosis in front, or are continued dorsally and laterally over into the dorsal constrictors.

The function of the constrictors is to compress the pharyngeal chamber, eject the water, and close the gill slits. The first dorsal constrictor may assist in raising the upper jaw, and the second may raise the hyoid arch, while the first and second ventral constrictors lower the under jaw and the hyoid respectively, thus assisting in the opening of the mouth.

Raia.

In removing the skin from the skate, there is less connective tissue than in Acanthias, the constrictors are not so conspicuous, and more muscles occur, as for instance those which control the rostrum. The muscles, too, have been altered in relative size and position in accordance with the modification of form in this extreme type, but the same general relations are easily followed.

The constrictors have increased in number to seven, and, associated with the extreme flattening of the branchial region, the dorsal and ventral constrictors are not continuous as in Acanthias, but are distinct, being separated at the lateral part of the branchial region by what Tiesing has called the horizontal tendon. This tendon starts from the lateral end of the hyomandibular cartilage, and running along the anterior surface of the gill region, connects with the propterygium and continues back in the lateral branchial region, affording insertion to both dorsal and ventral constrictors. Since the gill slits lie wholly upon the ventral surface, the ventral constrictors in turn have divided into median and lateral portions, the line of division occurring at the median ends of the gill clefts (Fig. 6).

Dorsal Constrictors.— The first dorsal constrictor (Fig. 6, *Csd 1*) takes its origin from the lateral labyrinth region of the skull, ventral and posterior to the postorbital process, and is continuous posteriorly with the levator maxillæ superioris, these two muscles, as in Acanthias, having a common origin. The fibers run forward, curving laterally along the anterior margin of the spiracle, and are inserted on the dorsal surface of the hyomandibula, a short distance from its anterior end. A sheet of fascia (*F*) to be described later, has a part of its origin from this muscle near its insertion; in part it also arises from the posterior margin of the spiracle.

The second dorsal constrictor (*Csd 2*) is larger and more differentiated than in Acanthias, having developed into distinct muscles with different functions — an anterior levator hyomandibularis and a posterior portion which agrees with the other constrictors in position and shape.

The levator hyomandibularis (*L Hm*) arises from the postero-

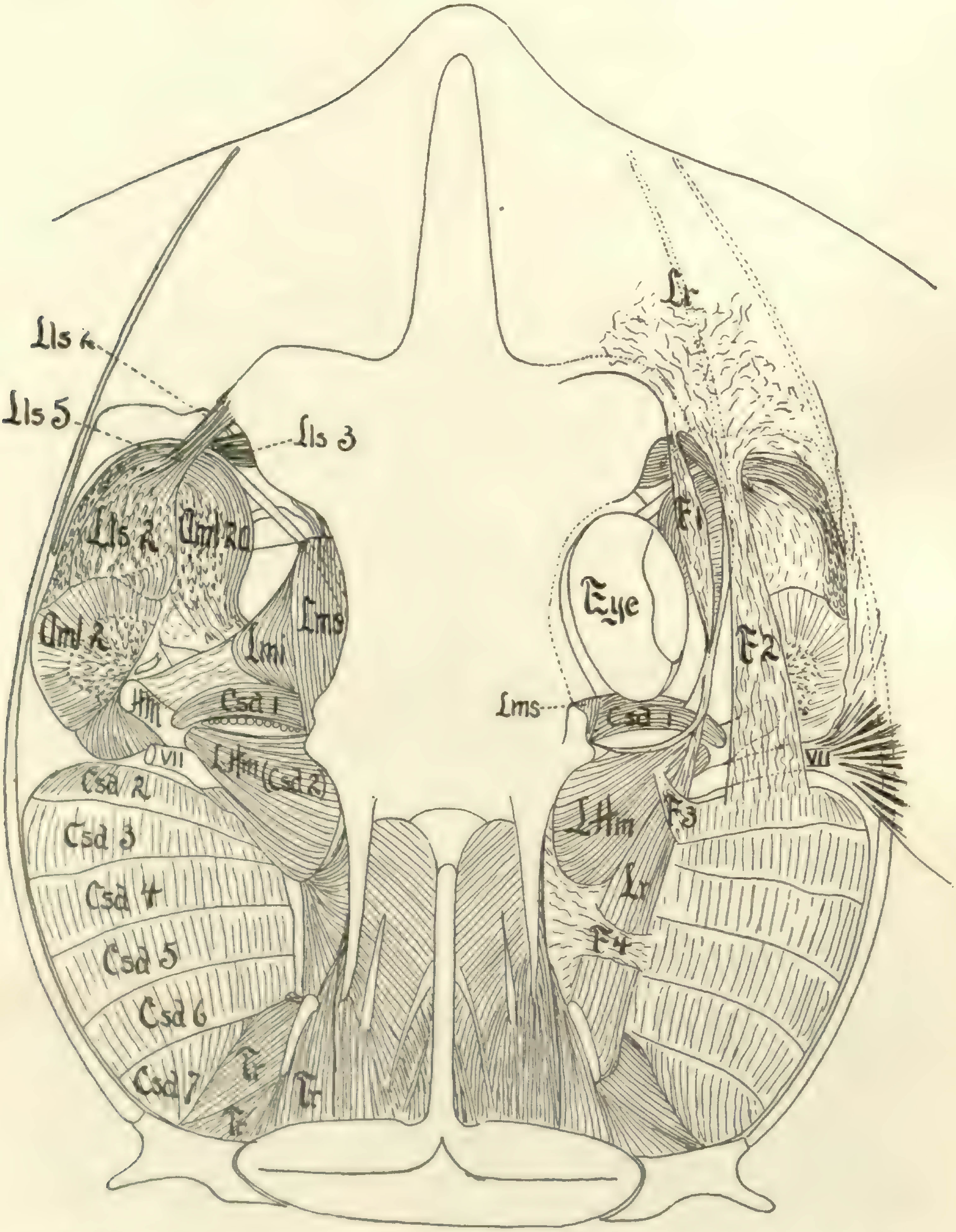

FIG. 6.— Dorsal view of Raia, more deeply dissected on the left. *Aml 2*, adductor mandibularis lateralis (superficial layer, posterior); *Aml 2a*, same, superficial layer, anterior; *Csd 1–7*, constrictores superiores dorsales; *F 1–4*, fasciæ; *HM*, hyomandibula; *LHm*, levator hyomandibularis; *Lls 2, 3, 5*, levatores labialis superioris; *Lmi*, levator maxillæ inferioris; *Lms*, levator maxillæ superioris; *Lr*, levator rostri; *Tr*, trapezius.

lateral part of the labyrinth region of the cranium. Its fibers run obliquely forward and outward, forming the posterior wall of the spiracle, while the large lateralis nerve penetrates the middle of the muscle in order to reach the region of the fin. The muscle is inserted upon the hyomandibula, the line of insertion beginning behind that of the first dorsal constrictor and extending the length of the rest of the cartilage. This muscle has become differentiated from the rest of the constrictor system and is only used to raise the hyomandibula.

The other more lateral and posterior portion of the second dorsal constrictor (*Csd 2*) is associated with the others of the series. Its fibers are entirely distinct from those of the levator hyomandibularis and arise from the tendon separating the second and third constrictors. This tendon is not so extensive as the succeeding and does not extend laterally to the horizontal tendon which is correspondingly interrupted opposite this point.

The remaining dorsal constrictors (*Csd 3–7*) are practically alike. Each arises from the tendon between itself and the next following muscle and is inserted on the tendon in front. The seventh forms an exception in that it is smaller than the others, and its fibers are not parallel to the main axis of the body, but converge to the point of origin upon the shoulder girdle. The intermuscular tendons incline more and more from the transverse direction as we go farther back, and, as the muscles extend to the horizontal tendon, they bend downward at the lateral margin in order to reach it. A few of the fibers of (*Csd 3*) are inserted in a strong tendon (*F 3*) which extends forward from the intermuscular tendon between constrictors 2 and 3, ventral to all the adductors of the jaws, to be inserted on the skull and surrounding tissue lateral to the nostrils.

The ventral constrictors (Fig. 3, *Csv*) are likewise seven in number. The first, instead of forming a broad sheet as in Acanthias, is divided into two portions, an anterior part, which extends from one mandibular half to the other just behind the symphysis, and a posterior portion. The anterior portion is not constantly present; I failed to find it in one specimen.

The posterior part of the first ventral constrictor is a flat fan-shaped muscle which arises in connection with the depressor

rostri (to be described later) in the fascia covering the coraco-arcualis communis, and is inserted upon the mandible at about the center of its posterior edge. This part of this ventral constrictor thus forms a distinct depressor mandibuli (*Dm*). Only the anterior edge of the origin of this muscle can be seen until the depressor rostri (Fig. 15, *Dr*) is removed, but the method of description necessitates its mention here.

The second ventral constrictor is likewise much modified from the condition in Acanthias, being divided into an anterior depressor hyomandibularis (*DHm*) and a posterior second ventral constrictor proper (*Csv 2*).

The depressor hyomandibularis has its origin in the fascia overlying (ventral to) the coraco-hyoideus, the fascia connecting the depressors of the two sides dorsal to the coraco-mandibularis. The general course of the muscle is transverse to the longitudinal axis of the body. The fibers converge from a broad flat origin to a cylindrical muscle which then runs dorsally and becomes inserted upon the posterior end of the ventral edge of the hyomandibula and upon the horizontal tendon. The posterior portion of the second ventral constrictor has its origin in part in the tendon (less developed than the others) separating it from the third ventral constrictor, while the more lateral fibers are continuous with those of the third constrictor, there being no aponeurosis between them. The fibers run forward, converging from either side toward their insertion on the horizontal tendon.

Each of the remaining ventral constrictors (*Csv 3*–*Csv 7*) is composed of two parts, a large median and a smaller lateral portion, the muscle becoming smaller toward the lower limits of the gill region. The tendons separating the constrictors (the first two are united medially) run obliquely outward and backward to the median ends of the gill slits and then turn abruptly and pass to the middle of the gill slit behind, so that this portion of the tendon serves to separate the median from the lateral parts of the muscle.

The origin of the median portion of the seventh ventral constrictor is from the fascia covering the ventral edge of the coraco-branchialis. The other muscles arise from the tendon

behind. In all, the fibers are inserted upon the tendon in front, and their courses are somewhat oblique near the median side, and nearly at right angles to the body axis at their outer margins.

The lateral portions of the constrictors arise from the tendons between them and the median muscle, and the fibers run laterally to some small cartilages (not always present) and then turn dorsally to be inserted on the horizontal tendon.

Interbranchiales.

Acanthias.

It is a question whether these should be included among the superficial circular muscles or not, since they are in no sense

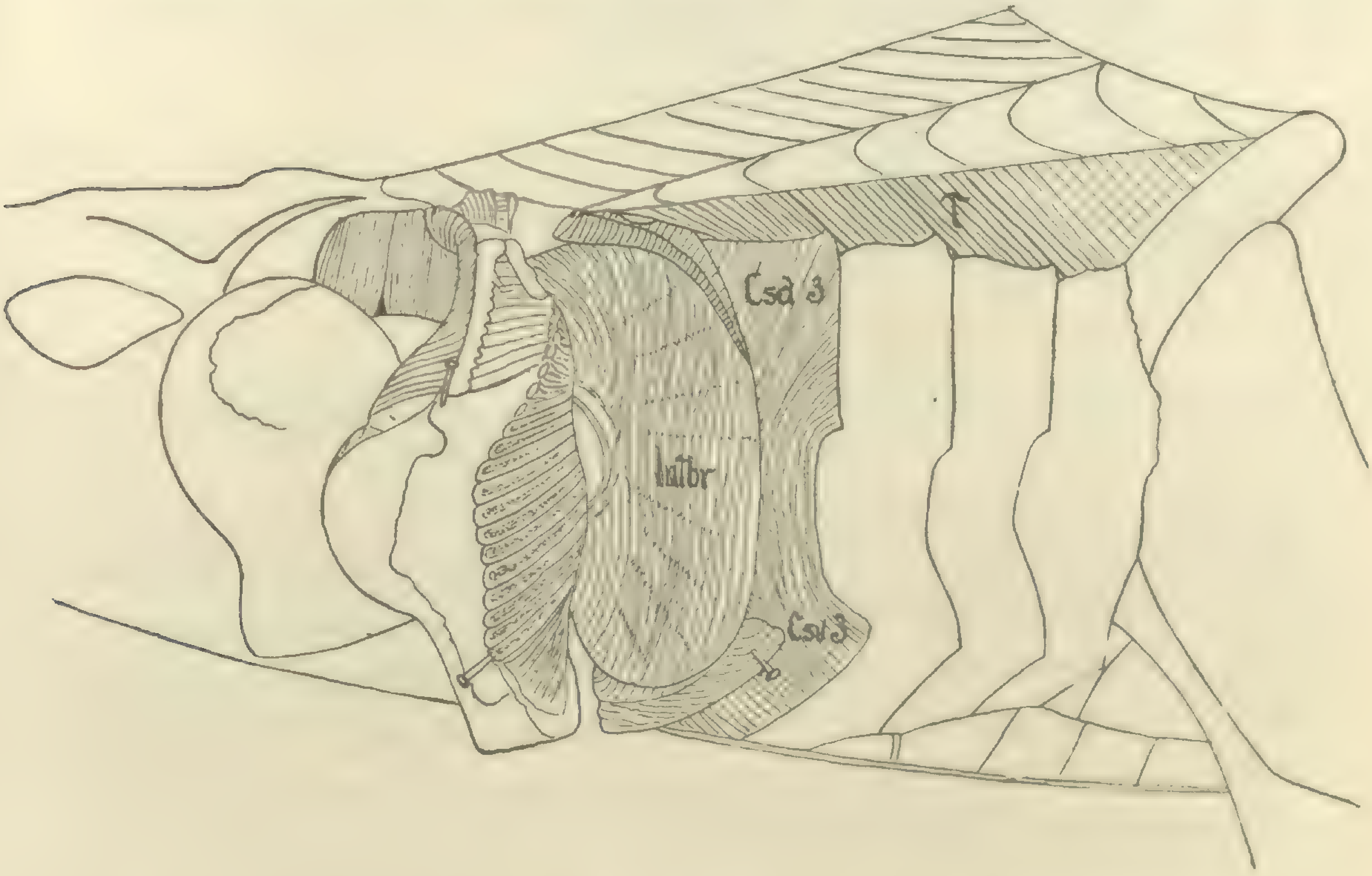

FIG. 7 — Lateral view of Acanthias to show the interbranchiales. *Csd 3*, constrictor superioris dorsalis 3; *Csv 3*, constrictor superioris ventralis 3; *Intbr*, interbranchialis; *T*, *trapezius*.

superficial, nor circular in the same sense that the other muscles are, and they lie in a different plane. However, they are closely allied with the constrictors in function, assisting in the general contraction and expansion of the gill basket, and since comparisons with Vetter are made easier, they are retained here.

These muscles (Figs. 5, 7, 8, 11, *Intbr*) are fewer in number and lie between the demibranchs of the four complete gills. Each is extremely thin and consists of a sheet of fibers, anterior to the cartilaginous gill rays, and extending between the gills

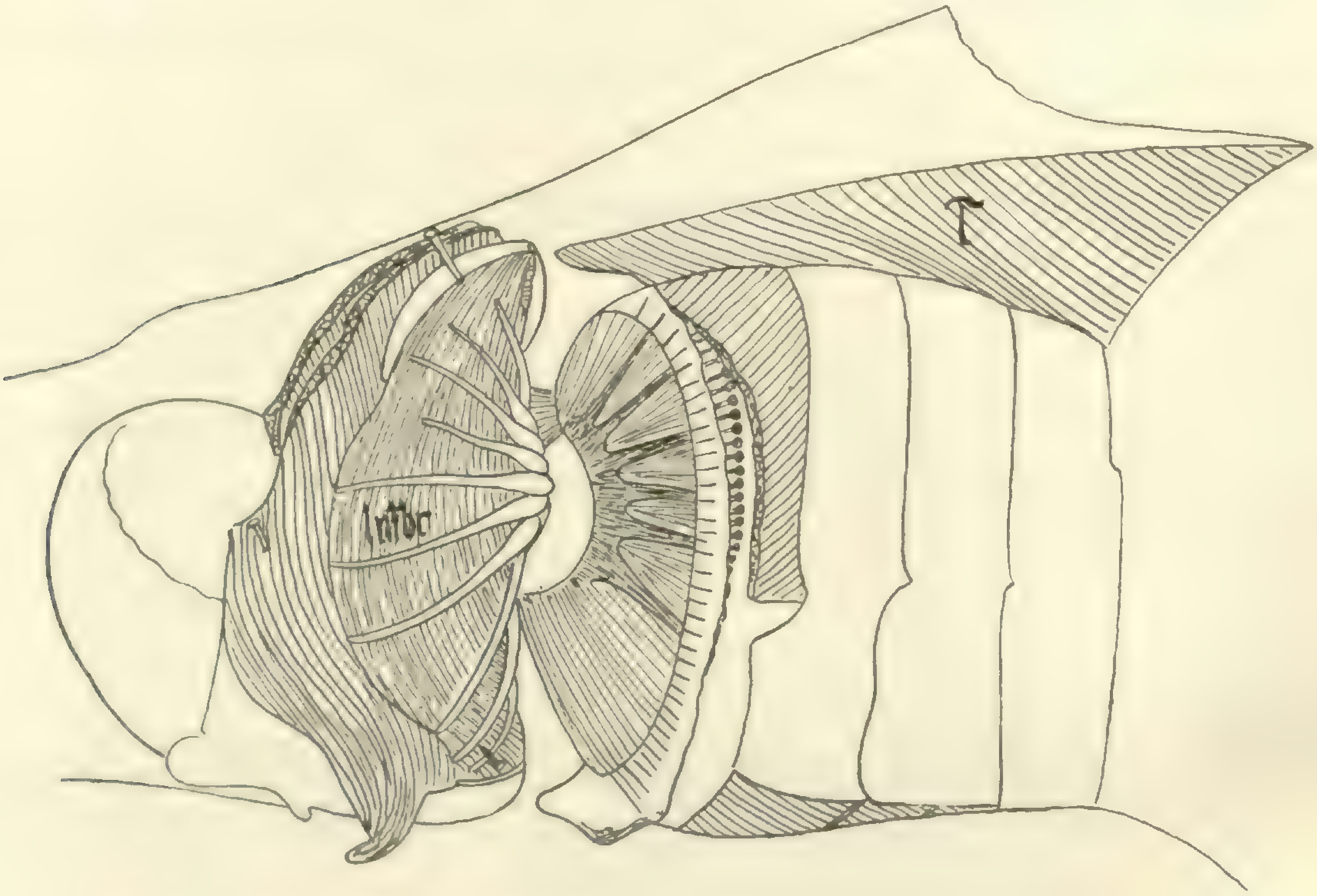

FIG. 8.—Lateral view of Acanthias, showing the interbranchiales (*Intbr*). *T*, *trapezius*.

from top to bottom of the septum. A tough white fascia extends from the dorsal longitudinal muscles to the extrabranchial cartilages, holding the latter in place below the aponeurosis between the dorsal constrictors, and connecting them with the interarcual muscles to be described later. The most dorsal of the interbranchial muscle fibers arise from the fascia just described, while the rest have their origin in the aponeurosis between the dorsal constrictors. The more median of the fibers curve outward and downward toward the median line, to become inserted on the anterior margin of the epibranchial cartilage (Fig. 7). The more lateral fibers are larger and follow a broad curve from the dorsal to the ventral side of the gill septum, and thus pass into the ventral fibers about to be described, just as the dorsal and ventral constrictors merge in part into each other.

The ventral fibers arise from the extrabranchials as well as

from the tendinous fasciæ connecting these cartilages, while the fibers on the median side arise from the fascia between the longitudinal muscles (Fig. 5 shows an instance of origin at the end of the common coraco-arcualis). This point is of some importance in the interpretation of the condition in Raia. The fibers near the middle line are inserted upon the anterior surface of the cerato-branchial cartilage, while the lateral fibers are continuous with those of the dorsal side as noted above. Often the muscle fibers stop at a gill ray, the tissue becoming aponeurotic, and then the muscle fibers continue on the other side.

These interbranchial muscles draw the gill radii together and thus aid in the contraction of the gill basket. In the case of the hyoid arch, the second dorsal and ventral constrictors replace the interbranchialis, since here the gill radii lie immediately beneath the surface (constrictor) muscles.

Raia.

The interbranchiales of Raia are much like those of Acanthias in position and number, the muscle of the first arch being replaced by the posterior part of *Csv2* and *Csd2*. Owing to the shape of the branchial region they do not form a continuous arc but are divided into a dorsal and a ventral portion, so that the line of division coincides with the angle separating the halves of each branchial arch. The muscle fibers of the dorsal portion arise from the aponeuroses between the dorsal constrictors, and run ventrally (Fig. 12) until they become inserted upon the dorsal surface of the epibranchial cartilages or upon the ray which runs out from the angle to the horizontal tendon. The ventral fibers take their origin from the tendons between the ventral constrictors and run dorsally to their insertion upon the ventral surfaces of the cerato-branchials or upon the horizontal ray just referred to. The fibers never become continuous, as in Acanthias, from dorsal to ventral surfaces. A few bundles of the most median fibers of the ventral portion are overdeveloped, and have extended so as to take their origin from fasciæ covering the coraco-mandibularis muscle (Fig. 3, *Intbr*). A similar condition was noted above for Acanthias but these fibers were not as

prominent there as here. Tiesing, basing his opinion on the work of Vetter upon Heptanchus, has regarded these fibers as a deeper layer of the constrictor but Acanthias shows this not to be tenable. There is no resemblance to a constrictor. In the case of the fourth arch the corresponding fibers extend into

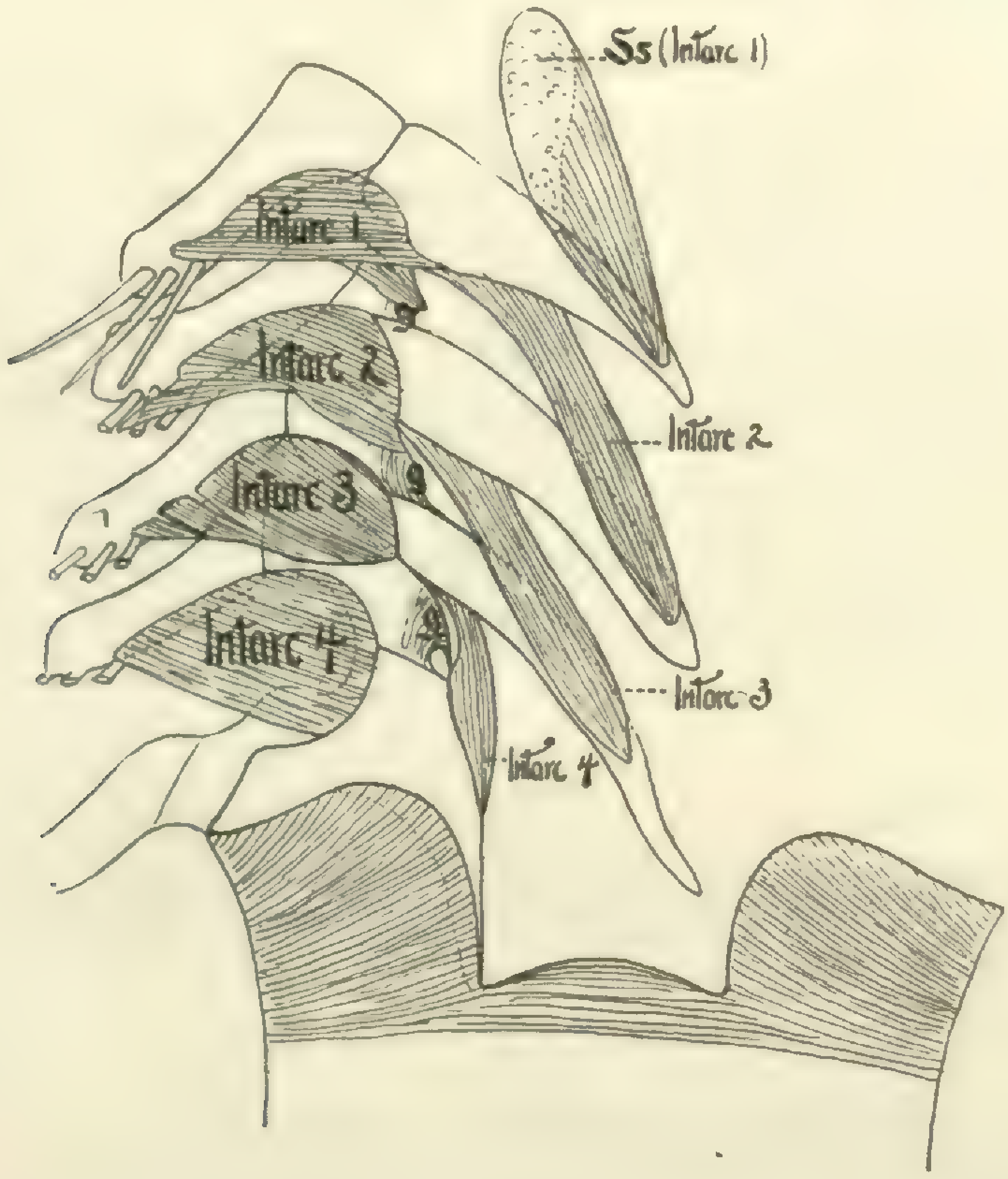

FIG. 9.—Dorsal view of gill arches of Acanthias to show the interarcuales. *g*, groove; *Intarc 1–4*, interarcuales; *Ss*, subspinalis.

tough tendons connected with the coraco-arcualis communis muscle (Fig. 3). On the dorsal side there is but one instance of this extension of the interbranchials (Fig. 6, at the inner posterior angle of *Csd 6*). A few fibers take their origin from the sides of the first vertebra. This could not be considered a constrictor.

Levator Maxillæ Superioris.

Acanthias.

This muscle (Figs. 2, 11, 14, *Lms*), already mentioned in connection with the first dorsal constrictor, arises in common with it from the lateral surface of the cranium just posterior to the

postorbital process. It is larger than the first dorsal constrictor and fills the entire bay back of the postorbital process. The fibers extend anteriorly and ventrally to their insertion on the dorsal margin of the palatal process of the upper jaw, just anterior to the attachment of the first dorsal constrictor. In fact the only distinction that can be drawn is that in the levator the fibers go directly to the jaw while those of the first dorsal constrictor curve around the anterior margin of the spiracle.

Raia.

In the skate the levator of the upper jaw (Figs. 3, 6) is composed of a thick dorsal and a thinner ventral layer, the two united at their point of insertion. The thicker layer (*Lms*) arises from the side of the skull, just ventral to the postorbital process, and its fibers run almost straight forward, then dorsal and backward in front of the oral cavity to their insertion on the upper jaw. The thinner and more ventral layer (*Lmi*) arises just below and behind the facial foramen whence its fibers run forward, laterally, and backward to unite with the dorsal layer. This course involves a strong lateral bend from which a strip of fascia extends to the hyomandibular cartilage (Fig. 6). Some of the more ventral fibers are inserted in the membranous wall of the roof of the mouth.

Tiesing maintains that the levator maxillæ superioris is only a deeper part of the first dorsal constrictor,— a view rendered very probable from the relations in Acanthias in which the conditions are the more primitive. It is very similar to a constrictor in origin and function, although differing widely in form.

Trapezius.

Acanthias.

The trapezius (Figs. 2, 7, 8, 11, *Tr*) has its origin in fascia covering the sides of the dorsal longitudinal muscles. Its fibers arise from a straight line extending from the posterior end of the cranium to the dorsal part of the shoulder girdle, although the

muscle extends through only the posterior three fourths of this. The fibers, which become thinner posteriorly, run obliquely downward and backward, the majority being inserted on the anterior edge of the pectoral girdle, while the more anterior fibers turn directly downward and are inserted on the dorsal edge of the last branchial arch. At intervals tendinous strands of the dorsal

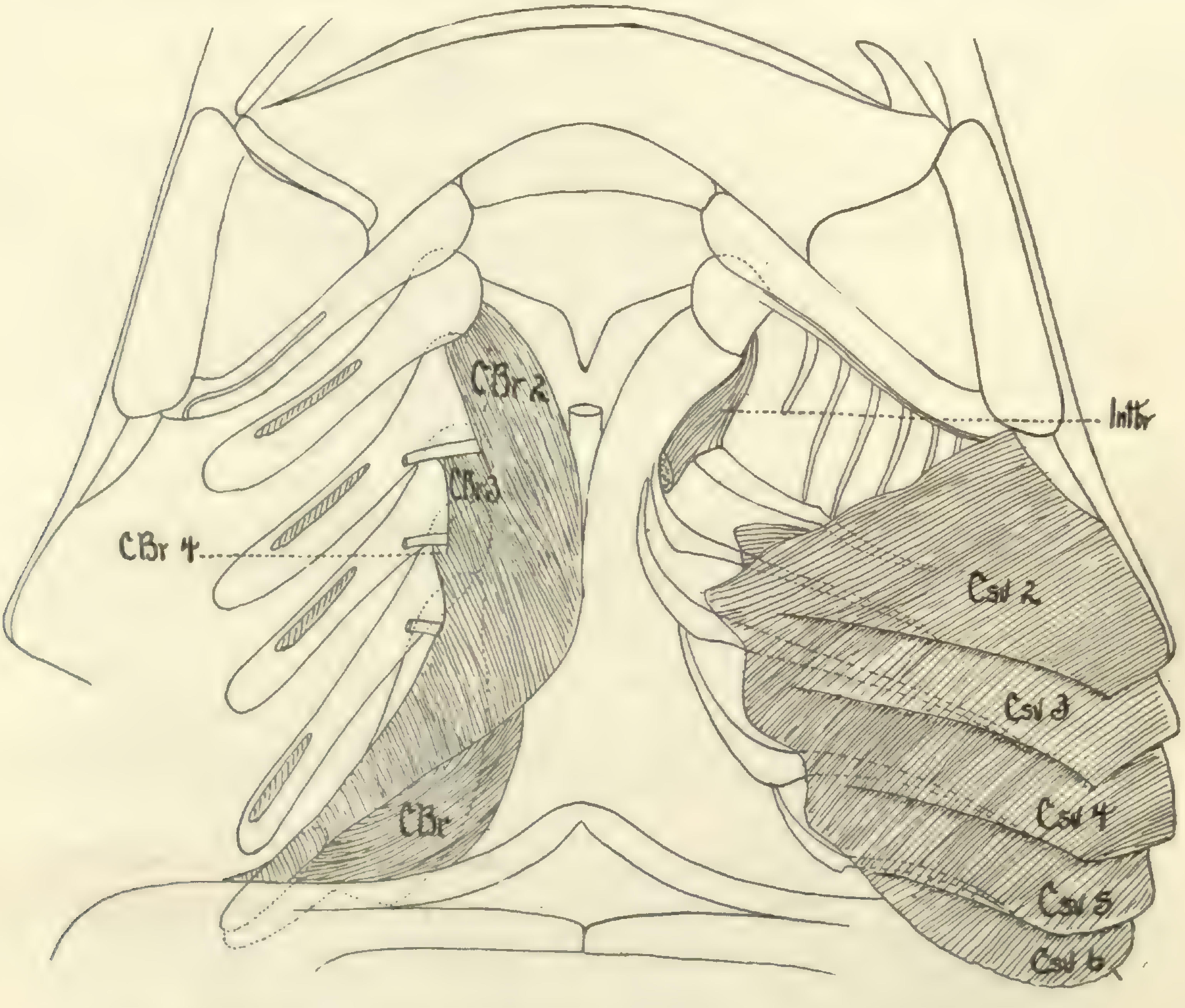

FIG. 10.— Ventral view of Acanthias showing the coraco-branchiales. *CBr*, coraco-branchiales; *Csd 2–6*, constrictores superiores dorsales; *Intbr*, interbranchialis.

constrictors (Fig. 11, *Csd*) as already described, pass through this muscle. The function of the trapezius is to raise the girdle and draw it forward.

Raia.

A trapezius has not been described in the skates but there occurs here a muscle (Fig. 6, *Tr*) which in its attachments and

the direction of its fibers somewhat resembles it although it does not in all respects fulfill the conditions found in Acanthias. There are here three parts to the muscle: a small median portion and two more lateral in position.

The median, the smallest, arises from the side of the first vertebra and its fibers run obliquely backwards to be inserted on the anterior edge and ventral surface of the suprascapula. The most lateral portion arises near the first and its fibers run obliquely backward and outward to the insertion upon the upper surface of the last visceral arch and on the anterior edge of the girdle far down towards the ventral edge. The remaining portion arises just ventral to the part just described and its fibers are attached to the scapular portion of the pectoral girdle. (In *Raia radiata* the median portion is greatly reduced and its origin is from the lateral process of the vertebra, just back of that of the next division.)

The two lateral portions of the muscle in Raia are apparently partly antagonistic, that first described elevating, the other depressing the girdle to a certain extent.

Levator Labialis Superioris.

Acanthias.

Although Vetter classifies this muscle among the adductors he says ('74, p. 448): "Er erscheint als seriales Homologon des M. levator max. sup. und aller der andern Theile des grossen Constrictors, welche vom Schadel oder von der epaxionischen Muskulatur zu der Visceralbogen gehen, und ist sonach passenden als M. levator labii sup. zu bezeichen." For this reason I have included it among the other similar constrictors. This muscle (Fig. 1, *Lls*) has its origin from the ventral surface of the cranium, in front of the basal process and to one side of the middle line. The fibers run outwards and backwards, describing an arc to the angles of the mouth where they converge to a straight fibrous tendon which passes dorsal to the labial cartilages, crosses the angle of the mouth at right angles, and is inserted among the fibers of the adductor mandibularis.

Raia.

The levator labialis superior in the skate has been differentiated into five parts (Figs. 3, 6, *Lls 1–5*). Of these the first (*Lls 1*) most nearly resembles the single muscle of Acanthias. It is small, cylindrical, and arises from the ventral surface of the cranium near the orbit and just behind the base of the ethmoid process. It runs laterally and then backward to the angle of the mouth, which it passes, to become inserted in the fascia

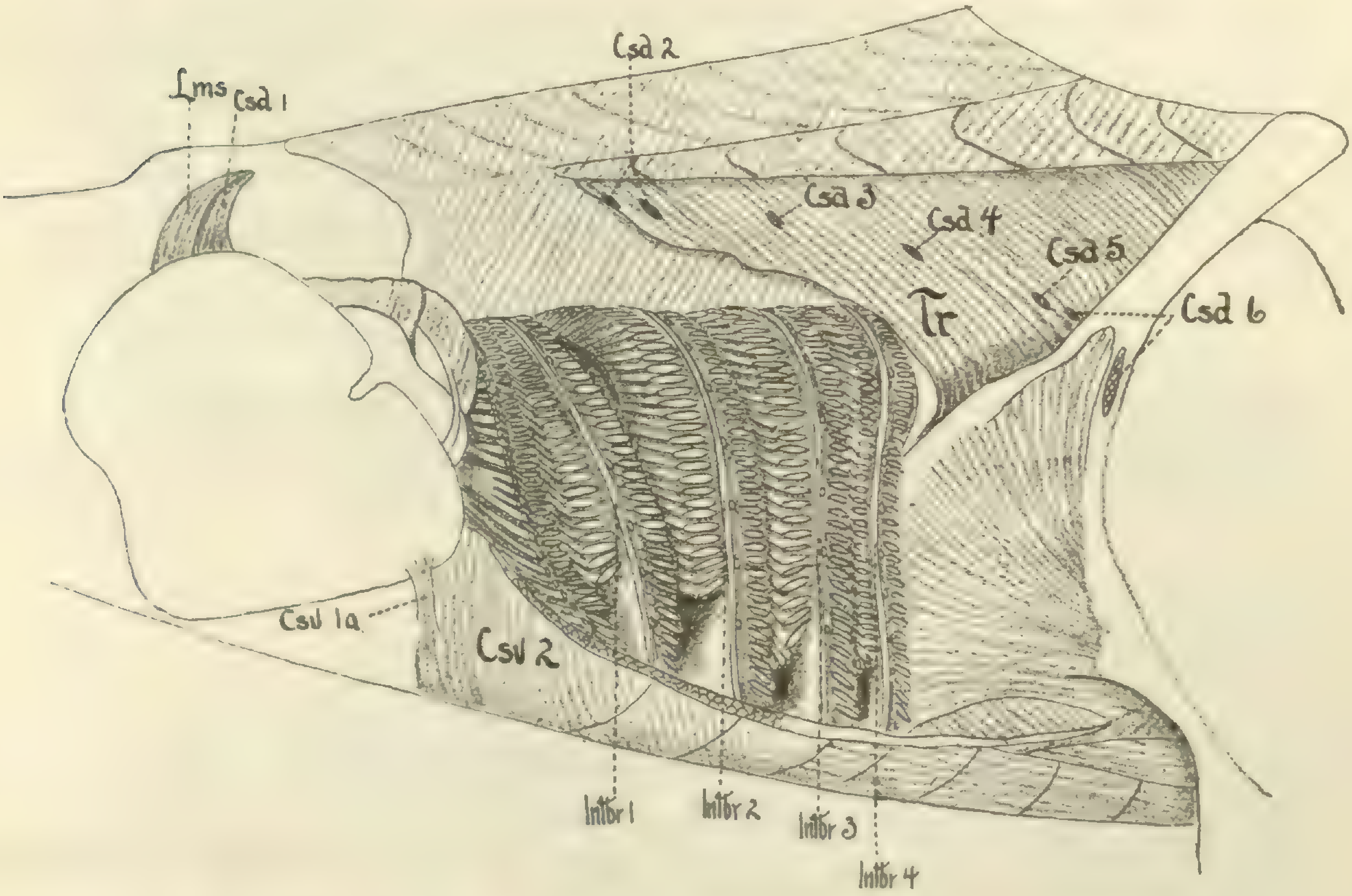

FIG. 11.—Lateral view of Acanthias showing interbranchiales and trapezius. *Csd 1–6*, constrictores superiores dorsales; *Csv 1a*, constrictor superioris ventralis, anterior fibers; *Csv 2*, constrictor superioris ventralis 2; *Intbr 1–4*, interbranchiales; *Lms*, levator maxillæ superioris; *Tr*, trapezius.

between the adductores mandibularis medialis and lateralis which it separates.

The second division (Fig. 6, *Lls 2*) is much the largest of the labial muscles. It arises from the dorsal surface of the most lateral part of the ethmoid region in front of the antorbital process. The origin is small and of rather soft fibrous material. After passing dorsally of the large mass of the adductor man-

dibularis lateralis *2a*, it widens into a large muscle which disappears under the adductor mandibularis lateralis 2 to become inserted on the mandibular cartilage while a portion of its fibers become confused with the posterior portion of *Aml* 2 (Fig. 3).

The third division (Fig. 6, *Lls 3*) is the smallest of the system: a short thick muscle running from the postero-lateral edge of the dorsal surface of the nasal capsule, laterally, to the posterior dorsal angle of the antorbital process, the fibers converging towards the insertion.

The fourth division (Fig. 3, *Lls 4*) is broad, thin, and flat, and its origin is continuous with and ventral to that of the third division. It lies upon the adductor mandibularis lateralis and covers a portion of it ventrally. The mandibularis branch of the fifth nerve runs between the two. Its general course is posterior and the fibers which are not inserted in the fascia covering the adductor mandibularis lateralis converge to a strong tendon, which makes its way through that muscle, to their insertion on the ventral surface of the mandible.

The fifth division (Fig. 6, *Lls* 5), though included by Tiesing among the muscles, is but a group of strong tendinous fibers having its origin just posterior to that of the second division and its insertion on the strong fascia enveloping that muscle. Muscular tissue is lacking in it, and it is scarcely more than a second origin of that muscle.

Levator Rostri.

This muscle (Fig. 6, *Lr*), together with the next, would be treated first among the superficial muscles were we describing Raia alone, but since it is lacking in Acanthias it has been left until now. Upon removing the skin from the dorsal surface, the levator rostri is the first seen and most superficial of the muscles. It takes its origin from the lateral edge of the lateral process of the first vertebra which projects above the surrounding muscles, and from the tendinous fascia covering the muscles in this region. The fibers run obliquely forward, converging to the region where they cross the levator maxillæ superioris and the first dorsal constrictor where they pass into a strong cylin-

drical tendon. This tendon continues forward, passing outside the spiracle and the eye and over the various jaw muscles and the antorbital cartilage, into the fascia of the rostral region where it is inserted in the strong membranous tissue stretching between the rostrum and the propterygium.

Depressor Rostri.

The depressor rostri (Fig. 15, *Dr*), the antagonist of the last, is a broad, flat, thin muscle arising from the fascia covering the coraco-mandibularis and from the fibers of the coraco-arcualis communis. The muscle extends forward and outward in the direction of the adductor muscles where some of the lateral fibers are inserted in the white fascia covering these muscles,[1] while the majority are collected into a strong tendon which extends forward, lateral to the nasal capsule and ventral to the antorbital process, then coming towards the median line is inserted in the membranous tissue between the tip of the rostral cartilage and the propterygium.

INTERARCUALES.

Acanthias.

The interarcuales (Fig. 9) are divided into two systems of muscles: one more medial, the other more lateral in position, each consisting of four muscles, similar in function, the first of the medial system being the subspinalis of Vetter ('74, p. 444).

Medial System.— The most anterior of the medial interarcuales has been treated as a distinct muscle, the subspinalis, by Vetter but as it agrees closely with the others in function and differs only in its origin from the rest, it is here regarded as but one of the set. Its origin is from the fascia on the under side of the dorsal longitudinal muscles, from the vertebræ near the cranium, and from the under side of the cranium itself just in front of the foramen magnum. From this broad origin it

[1] In *Raia radiata* most of the fibers have this insertion, while a small proportion are continued into the rostral depressor tendon.

tapers to a tendon which is inserted upon the dorsal posterior end of the first pharyngo-branchial. It draws the first pharyngo-branchial forward in the same way that the succeeding muscles draw the pharyngo-branchials upon which they are inserted.

The second, third, and fourth medial interarcuales arise from the posterior surface of the first, second, and third pharyngo-branchials respectively, a little in front of the middle of each and are inserted upon the dorsal surface of the second, third, and fourth pharyngo-branchials. The point of attachment is at about the middle of the cartilage except in the case of the second where the attachment is behind the middle. These muscles have a larger surface of insertion than of origin and decrease in size from in front backwards.

Lateral System.— A description of the first of the four will answer for the first three muscles of this system. The first lateral interarcuale has a double origin. The majority of the fibers arise from the posterior edge of the anterior end of the first pharyngo-branchial and a few from the anterior end of the second pharyngo-branchial just in front of the groove (*g*) for the passage of the blood vessel. The fibers are inserted on the dorsal surface of the epibranchial along a line which is a continuation of the line of insertion of the interbranchial muscle. Some of the fibers are inserted so far laterad as to be in front of the most dorsal gill rays, so that the muscle appears to be almost a portion of the interbranchial which has been forced deeper for its origin. The last lateral interarcuale differs from the rest only in its origin. Since the fourth and fifth pharyngo-branchials are fused the origin is not divided.

Raia.

The interarcuales are much reduced in the skate; indeed only the lateral system persists while the medial system is represented by non-muscular membranes connecting the pharyngo-branchial cartilages in the same way. Each of the muscles of the lateral system arises from the posterior edge of the anterior end of the pharyngo-branchial and is inserted upon the medial end of the epibranchial of the same arch.

It may be a question whether the interbranchiales, the interarcuales, and the adductores (next to be described) do not form a system of deep as opposed to the superficial constrictors. Each contributes toward the constriction of the whole branchial region, and, with the exception of the largest mandibular adductor, each lies beneath the more superficial system.

ADDUCTORES.

The adductor muscles draw together the ventral portions of each visceral arch. In the case of the mandibular arch they close the mouth, while in the gill arches they occur at the lateral hinge and approximate the ceratobranchial and epibranchial portions of each. The adductors of the first (mandibular) arch are enormously developed in correlation with the use of these parts, while those of the gill arches are very small. In Acanthias the adductors are much simpler than in Raia.

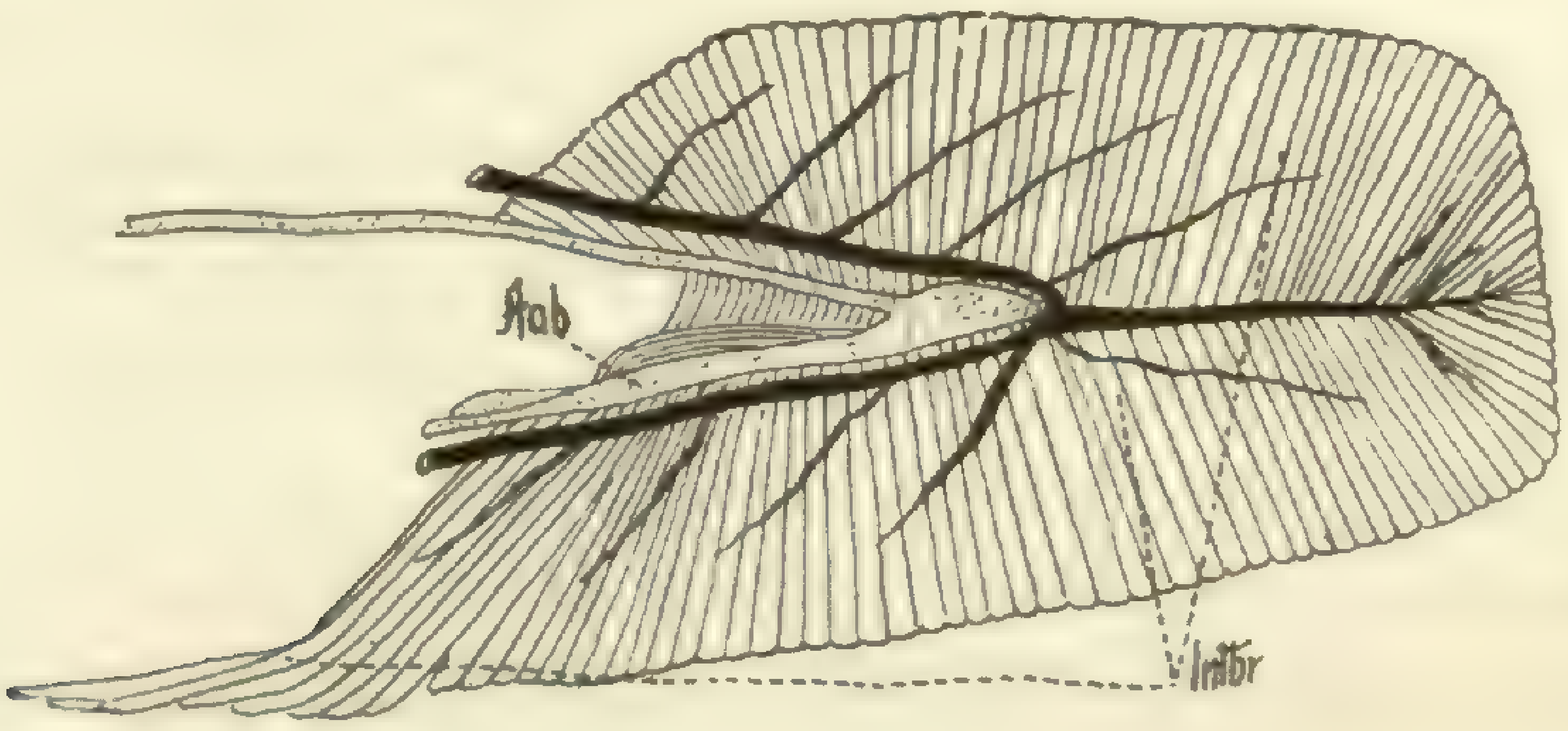

FIG. 12.— Anterior side of interbranchial muscle of Raia. *Aab*, adductor arcus branchialis: *Intbr*, interbranchiales.

Adductores Mandibulares.

Acanthias.

The mandibular adductor (Figs. 1, 2, 13, 14, *Am*) has a very strong tendinous envelope. Its fibers arise from the quadrate region of the upper jaw, and are attached to the entire lateral surface as well as to the medial surface of the muscle process on its dorsal margin. The course of the fibers is down-

ward and backward to the lower jaw where they are attached to the entire width of Meckel's cartilage. The details of the course of the fibers are rather difficult to express. On the lower jaw (Fig. 1) they extend nearer to the middle line than on the upper, and this portion (*x*) instead of coming from the fascia which separates it from the rest, comes from the posterior part of the upper jaw. A strong tendon is attached to this part which runs forward into the levator labialis superioris muscle. Other fibers are specialized in function. A broad thin sheet of fibers is extended on the upper half of the adductor and has its true origin from the under surface of the postorbital process, while a strong mass of tendinous material at the angle of the eye (Fig. 13, *y*) gives origin to some of the fibers. A few fibers of the first ventral constrictor, which have already been referred to as *Csv 1a*, are attached to the outer surface of the adductor.

Raia.

In the skate the adductor muscles are more complicated. They cover and surround the lateral ends of the jaws and are divided into distinct and easily separated layers. Following Tiesing, they may be grouped into a small medial, and a larger lateral portion, the latter in turn divisible into deeper and superficial layers.

Adductor Mandibularis Medialis.— This, the smallest of the adductors (Figs. 3, 6, *Amm*) arises from the anterior edge of the upper jaw. Its fibers run back across the angle of the mouth and then medially to become inserted near the anterior (occludent) margin of the lower jaw not far from the symphysis. Its origin is in common with the deeper layer of the lateral adductor and the two separate where the levator labialis superioris passes to become attached to the fascia between them.

The *adductor mandibularis lateralis* is subdivided into a deep layer (Figs. 3, 6, *Aml 1*.) and a more superficial portion (*Aml 2* and *Aml 2a*). The deep layer is largely covered by the superficial. The majority of its fibers arise from the anterior edge of the upper jaw as well as from the entire outer surface of the muscle process, and they find their insertion upon the outer surface of the lower jaw about opposite the point of origin.

The second division of the levator labialis superior, in its course to its insertion on the ventral surface of the lower jaw, crowds into the superficial layer of the lateral mandibular adductor, separating it in part into anterior and posterior portions. The anterior of these divisions (*Aml 2a*) arises in part from the dorsal surface of the lower jaw, directly opposite to its point of attachment to the deeper layer, and in part from the ventral

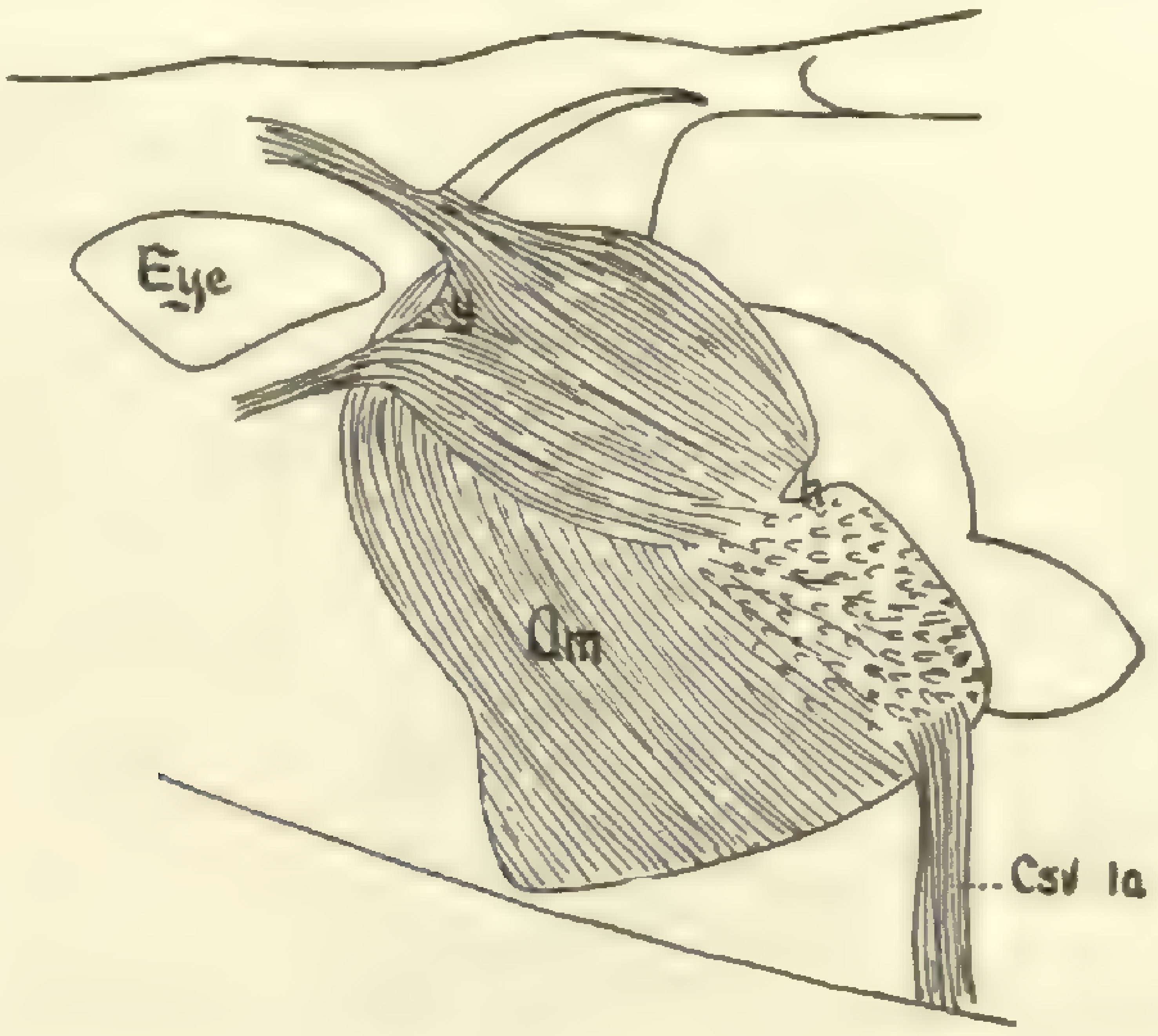

Fig. 13.— Lateral view of adductor mandibularis of Acanthias. *Am*, adductor mandibularis; *Csv 1a*, constrictor superioris ventralis, anterior fibers; *y*, tendinous mass back of eye.

surface by means of a very strong fibrous tendon. It runs forward, passing dorsally to the upper jaw and immediately broadens out into a large mass of fibers which curve ventrally and run backward, covering the deeper layer of the adductor and finally becomes inserted upon an aponeurosis surrounding the deeper layer. From this aponeurosis the fibers start again and continue backward, completely encasing the ends of both jaws, to the insertion directly and by means of tendons upon the lower jaw.

Adductores Arcus Branchialis.

The hyomandibular and hyoid cartilages are bound together at their articulation by strong ligaments, but no adductors are present connecting the two. In the branchial arches proper such muscles occur.

Acanthias.

A few short adductor muscle fibers extend between the cerato- and epibranchial cartilages of each branchial arch. They have their origin in small grooves on the inner surface of the epibranchials and are inserted in similar grooves on the inner (dorsal) surfaces of the ceratobranchials. Their function is to flatten the branchial region.

Raia.

In the skates (Fig. 12, *Aab*) the adductors of the branchial arches closely resemble those of Acanthias. They arise from

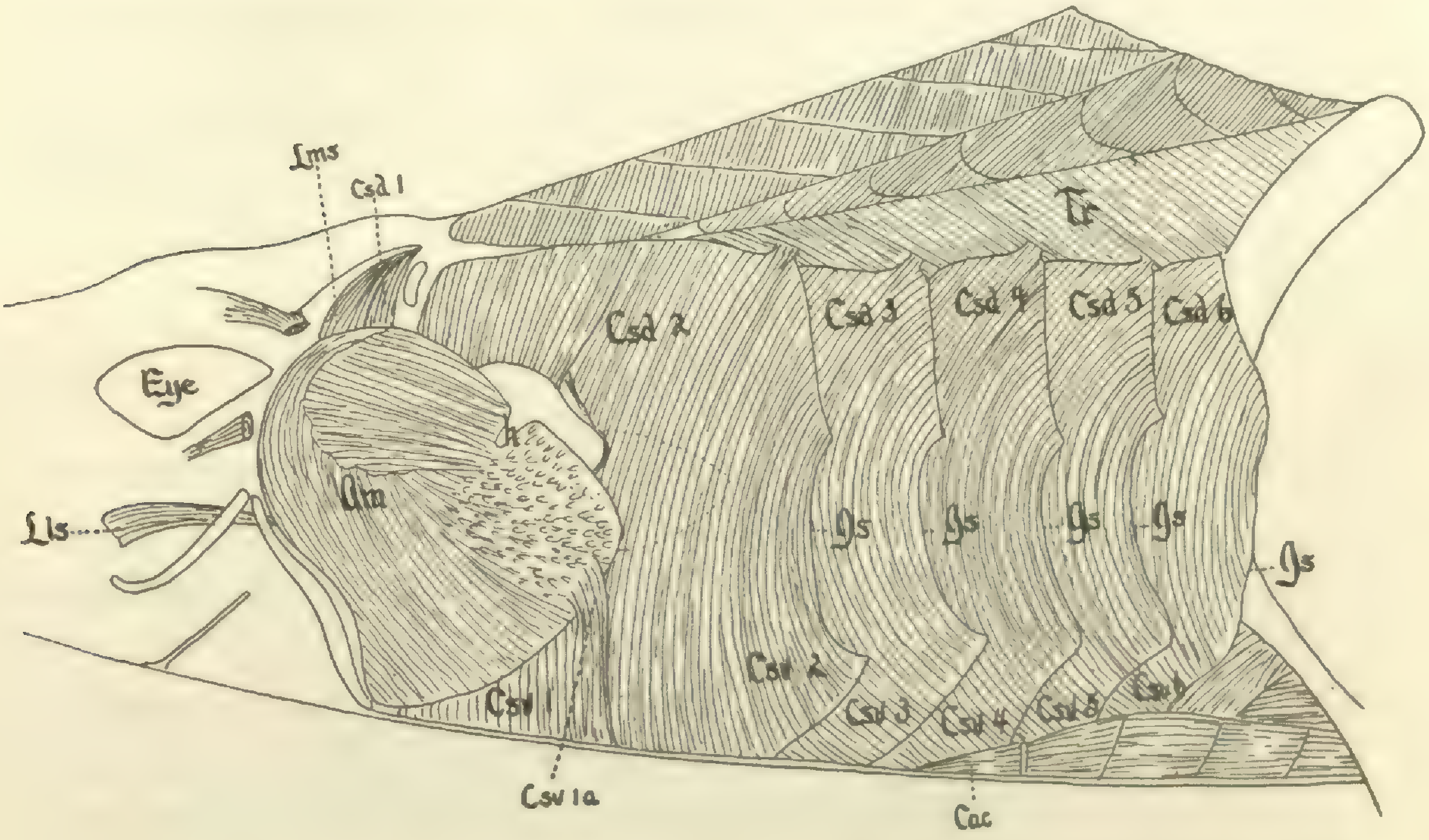

Fig. 14.— Side view of Acanthias after removal of the skin. *Am*, adductor mandibularis; *Cac*, coraco-arcualis communis; *Csd 1–6*, constrictores superiores dorsales; *Csv 1–6*, constrictores superiores ventrales; *Csv 1a*, constrictor superioris ventralis, anterior fibers; *Gs*, gill slits; *h*, hinge of jaws; *Lls*, levator labialis superioris; *Lms*, levator maxillæ superioris; *Tr*, trapezius.

and are inserted in similar grooves in epi- and ceratobranchial cartilages, while a few of the fibers extend some distance along the ceratobranchial before finding their insertion.

VENTRAL LONGITUDINAL MUSCLES.

The location and character of these muscles is apparent from this name. In Acanthias they are usually thick and solid, while, correlated with the depressed body, they are flat and thin in Raia.

Coraco-mandibularis.

Acanthias.

In the dogfish the coraco-mandibularis is an azygos muscle lying in the median line of the body, and is exposed (Fig. 5, *Cm*) by removing the ventral constrictors. It is the most superficial of the ventral longitudinal muscles. It arises from the fascia between the coraco-arcuales communes and its fibers rapidly diverge near the origin, where the muscle is nearly circular in section, to form a flattened band which is inserted on the posterior edge of the lower jaw on either side of the symphysis.

Raia.

In the skate the coraco-mandibularis (Figs. 3, 15, *Cm*) also lies in the median line but is not covered by the ventral constrictors, since these are here more lateral in position, with the exception of a few fibers (Fig. 3, *Csv 1*) already described. In origin and insertion there is a close agreement with Acanthias, but the muscle is thinner and flatter than in that form. With the exception of the depressor rostri and the depressor mandibuli, whose origins overlap its margin, it is the most superficial of all the ventral muscles.

Coraco-hyoideus.

Acanthias.

The coraco-hyoideus muscles (Fig. 4, *Chy*) are exposed by removing the coraco-mandibularis, which lies close to the median line. They are the largest of the ventral longitudinals.

The origin of each is very long, extending along the fibrous aponeurosis between it and the coraco-branchialis and the coraco-arcualis communis, from beneath the origin of the coraco-mandibularis halfway to its insertion on the ventral side of the hyoid copula just behind the lower jaw. The muscle is as thick as broad and only diminishes slightly in size in front.

Raia.

In the skate the coraco-hyoideus muscles (Fig. 3, *Chy*) are reduced, flat, and thin. Each arises from the fascia covering the large coraco-hyomandibularis, near the origin of the second interbranchial muscle and is inserted upon the ventral surface of the hypohyal cartilage. It lies deeper than the depressor rostri, the depressor mandibularis, and the depressor hyomandibularis, and directly upon the coraco-hyomandibularis.

Coraco-branchialis.

Acanthias.

The coraco-branchialis (Figs. 4, 10, *Cbr*) is the deepest and most dorsal of the ventral longitudinal muscles and forms the lateral wall of the pericardial cavity. It is composed of five parts, of which the last four have a common origin. The first division (*Cbr 1*) arises from an aponeurosis directly beneath the coraco-hyoideus, and running dorsally becomes inserted on the dorsal surface of the medial end of the hyal cartilage. It is much shorter than the ceratohyoid and is contracted near its insertion.

The four remaining coraco-branchials (Fig. 10, *Cbr 2–4*) arise from a strong membrane running from the girdle to the origin of the ceratohyoid. As the fibers pass forward and laterally they divide into separate portions, the anterior of which becomes inserted on the branchial arches, while the last, which is much the largest, is inserted upon the fifth arch and upon the lateral half of the copula. Blood vessels pass through the arches between the divisions of the muscle.

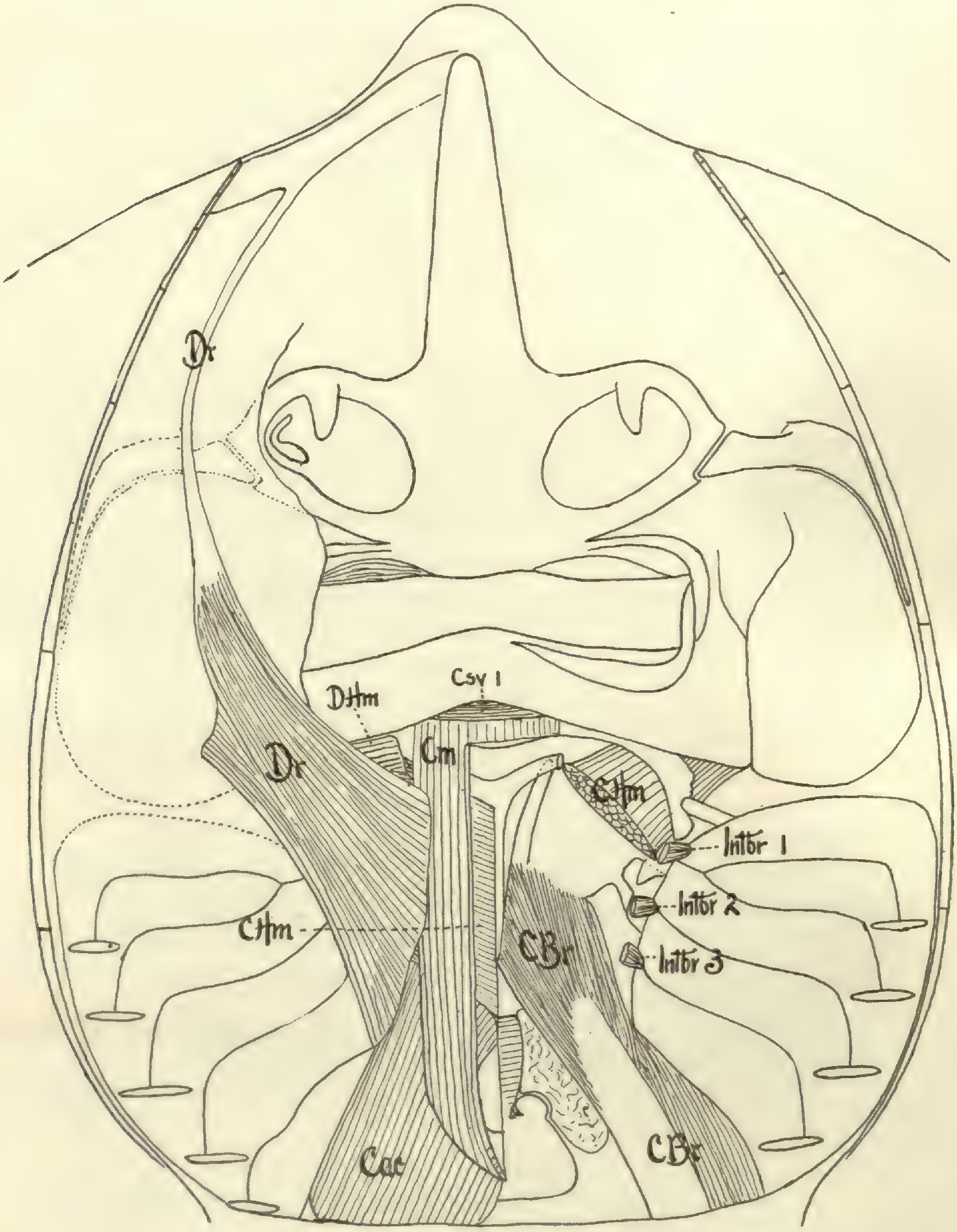

FIG. 15.— Raia, ventral view, after removal of the skin; right half more deeply dissected. *Cac*, coraco-arcualis communis; *CBr*, coraco-branchialis; *CHm*, coraco-hyomandibularis; *Cm*, coraco-mandibularis; *Csv 1*, constrictor superioris ventralis 1; *DHm*, depressor hyomandibularis; *Dr*, depressor rostri; *Intbr 1–3*, interbranchiales.

Raia.

In Raia this muscle (Fig. 15, *Cbr*) which forms the lateral wall of the pericardial cavity, arises from the pectoral girdle. Farther forward the muscle expands and the tendon gives place to muscle fibers which are inserted on the anterior process of the basibranchial and the membranous floor of the mouth. The other fibers run dorsally and become attached to the ends of the cerato- and hypobranchials. The divisions between these parts, as in Acanthias, permit the passage of blood vessels, and extend nearly back to the origin dividing the muscles into superimposed layers.

Coraco-arcuales communes.

Acanthias.

The paired coraco-arcuales communes muscles (Figs. 4, 5, *Cac*) lie immediately beneath the skin and arise from the coracoid region of the girdle. The fibers run inward and forward, and the medial fibers become inserted in the strong membrane which forms the floor of the pericardium, while the lateral parts are inserted upon the fascia dorsal to the origin of the ceratohyal. Each muscle is crossed by four myosepta, which makes it resemble somewhat the ventral body muscles behind the girdle.

Raia.

In the skate (Figs. 3, 15, *Cac*) this muscle closely resembles that in Acanthias in origin, direction, and insertion.

Coraco-hyomandibularis.

This wide, comparatively thick, and long muscle occurs only in Raia (Figs. 3, 15, *Chm*) of the forms studied, where it is the largest and most important of the ventral longitudinal muscles. It arises from a fascia in the middle line, and runs forward nearly to the division of the ventral aorta. The muscle runs obliquely

forward and outward, passes the first hypobranchial on the dorsal side, and converges to a small flat tendon on the anterior ventral surface of the hyomandibula.

Summary.

In the foregoing, all of the muscles of the head and the branchial region, with the exception of the eye muscles, have been considered. The two forms studied agree very closely when their difference in shape is considered.

In the skate, as might be expected from its extreme modification, a few muscles are developed which are not found in the dogfish. These are the levator and depressor of the rostrum, and the cerato-hyomandibularis which, from its position, seems adapted to the protrusion of the jaws.

The muscles of the skate referred to by Tiessing as "*Csvp 3–5*," are here interpreted as fibers of the interbranchials which have acquired an extreme development.

The muscles in Acanthias, marked *Csv 2* and *Csβ 2* by Vetter, are here regarded as the first and second ventral constrictors respectively.

The deeper ventral longitudinal muscles of Raia are described for the first time.

LITERATURE.

Drüner, L.

:03. Ueber die Musculatur des Visceralskelettes der Urodelen. *Anat. Anz.*, vol. 23, pp. 545–571, 16 figs.

Tiesing, B.

'95. Ein Beitrag zur Kenntnis der Augen-, Kiefer-, und Kiemenmuskulatur der Haie und Rochen. *Jen. Zeitschr. f. Naturw.*, vol. 30, pp. 75–126, pls. 5–7.

Vetter, B.

'74. Untersuchungen zur vergleichenden Anatomie der Kiemen- und Kiefermusculatur der Fische. *Jen. Zeitschr. f. Naturw.*, vol. 8, pp. 405–458.

OCCURRENCE OF *ECHINOSTOMUM SPINULOSUM* RUD.

N. C. GILBERT.

IN THE intestinal cœca of an adult male Loon (*Gavia imber*) killed near Ann Arbor, Michigan, in April, 1904, I found from forty to fifty mature distomes, which I have identified as *Echinostomum spinulosum* Rudolphi, a worm which I have not been able to find hitherto reported for North America. Later, in August of the same year, I obtained eight more specimens from the intestine of a Bonaparte's Gull (*Larus philadelphia*). In each case the specimens were in a badly macerated condition.

There was this unimportant difference from the European species, that my specimens averaged somewhat smaller. Their length was about 2.37 mm., while the length for the European species is given as from 3–10 mm. (Stossich, '92). The anatomical differences are also very slight between this species and *E. pseudoechinatum* Olsson, *E. euryporum* Loos, *E. mordax* Loos, and *E. pendulum* Loos, and make this species very difficult to differentiate. These differences are, however, very accurately described by Loos ('99), and although slight, seem constant.

The body of the specimens which I obtained is elongated, subcylindrical, widest at the acetabulum, and tapers gradually posteriorly. Length, 2.37 mm.; width at acetabulum, 0.29 mm. The neck is constricted, and is armed with spines, arranged in regular rows, which extend as far as the posterior border of the acetabulum. The anterior end is conical in shape, with an expanded base, and is armed with twenty-two oral spines, in a single row, and of equal size.

The oral sucker is located at the extreme anterior end; diameter, 0.08 mm. The acetabulum is located 0.61 mm. from the anterior end; diameter 0.17 mm. The pharynx is located close behind the oral sucker, and the intestine divides just anterior to

the acetabulum into two cœca of equal length, which extend to the posterior extremity.

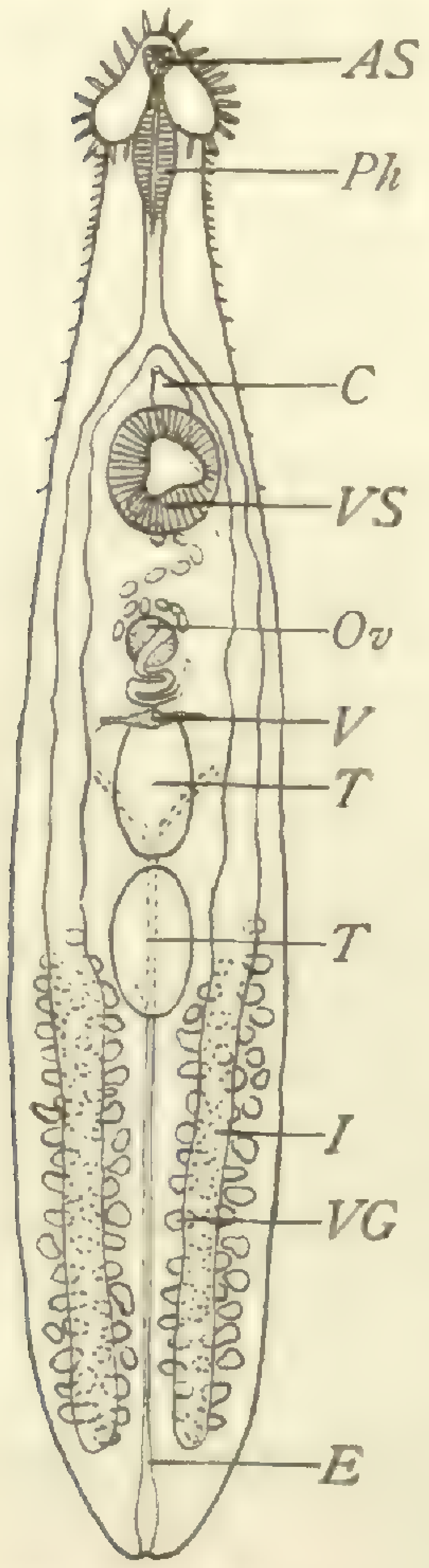

Fig. 1. — *Echinostomum spinulosum*. *as*, anterior sucker; *ph*, pharynx; *c*, cirrus-sac and seminal vesicle; *vs*, ventral sucker; *ov*, ovary; *v*, vitelline receptacle; *t*, testis; *i*, intestine; *vg*, vitelline glands.

The ovary is situated 0.15 mm. back of the acetabulum, in the median line, is round, and is 0.05 mm. in diameter. The oviduct passes posteriorly, makes two simple coils, receives the vitelline duct, and is surrounded by the shell gland. It then passes anteriorly, and after a few turns, it opens to the exterior just anterior to the acetabulum, and beside the cirrus-sac. The ova are rather large, oval, 0.09 by 0.06 mm., and from four or five to twenty-four were counted in one individual.

The vitelline glands consist of a large number of simple follicles, and extend as far anteriorly as the anterior border of the posterior testis. They are scattered over the entire region as far back as the ends of the intestinal cœca, and show a distinct bilateral arrangement. They open by two lateral ducts into a median receptacle, just anterior to the testis.

The testes are oval and relatively large, and located in the same antero-posterior line; length, 0.17 mm. by 0.12 mm., and 0.03 mm. apart.

The cirrus-sac and seminal vesicle lie just beneath the anterior margin of the acetabulum, and open to the exterior a short distance anterior to it.

LITERATURE.

Baird, W.

'55. Catalogue of the Species of Entozoa, or Intestinal Worms, contained in the Collection of the British Museum. London, 132 pp., tab. 1–2.

Creplin, F. C. H.

'46. Nachtrage zu Gurlt's Verzeichniss der Thiere bei welchen Entozoa gefunden worden sind. *Arch. f. Naturgesch.*, vol. 12, pt. 1, pp. 129–160.

Diesing, C. M.

'50. Systema Helminthum. Vindibonæ, 680 pp.

Diesing, C. M.

'58. Revision des Myzhelminthen, Abtheilung Trematoden. *Sitzungsb. kaiserl. Akad. Wissensch. Wien*, vol. 32, pp. 307–370, pls. 1–2.

Dujardin, F.

'45. Histoire naturelle des helminthes. Paris, iv + 654 + 15 pp., 12 pls.

Linstow, O. von.

'77. Enthelminthologica. *Arch. f. Naturgesch.*, vol. 43, pp. 173–198, pls. 13–14.

Loos, A.

'99. Weitere Beiträge zur Kenntniss der Trematoden-Fauna Ægyptens. *Zoöl. Jahrb., Abth. f. Syst.*, vol. 12, pp. 521–784, pls. 24–32.

Molin, R.

'58. Prospectus Helminthum quæ in Prodromo Faunæ Helminthologicæ Venetiæ continentur. *Sitzungsb. kaiserl. Akad. Wissensch. Wien*, vol. 30, pp. 127–158.

Molin, R.

'61. Prodromus Faunæ Helminthologicæ Venetiæ, adjectis Disquisitionibus Anatomicis et Criticis. *Denkschr. kaiserl. Akad. Wissensch. Wien*, vol. 19, pp. 189–338.

Rudolphi, C. A.

'08–'10. Entozoorum, sive Vermium Intestinalium Historiæ Naturalis, Amstelaedame. Vol. 2, 386 pp.

Rudolphi, C. A.

'19. Entozoorum Synopsis. Berlin, 811 pp., 3 pls.

Stossich, M.

'92. I distumi degli uccelli. Trieste, 54 pp.

NOTES AND LITERATURE.

BOTANY.

The Journals.— *Bulletin of the Torrey Botanical Club*, March :— Rydberg, "Studies on the Rocky Mountain Flora"; House, "Two New Species of Convolvulus from the Western United States"; Harper, "Phytogeographical Explorations in the Coastal Plain of Georgia in 1903."

Bulletin of the Torrey Botanical Club, April :—Evans, "New or Noteworthy Hepaticæ from Florida"; Eastwood, "New Species of Western Plants"; Maxon, "A New Botrychium from Jamaica"; Cushman, "Notes on the Zygospores of Certain New England Desmids, with Descriptions of a few New Forms."

Bulletin of the Torrey Botanical Club, May :— Toumey, "Notes on the Fruits of some Species of Opuntia"; Howe, "Phycological Studies — I. New Chlorophyceæ from Florida and the Bahamas"; House, "Notes on New Jersey Violets"; Britton, "Bryological Notes — II."

Bulletin of the Torrey Botanical Club, June : — Evans, "Hepaticæ of Puerto Rico — V. Ceratolejeunea"; Underwood, "A Summary of Charles Wright's Explorations in Cuba"; Kauffman, "The Genus Cortinarius — a Preliminary Study"; Berry, "A Ficus confused with Proteoides."

The Fern Bulletin, April : — Eggleston, "The Fern Flora of Vermont"; Clute, "What Constitutes a Species in the Genus Isoetes"; Flett, "Observations on *Lycopodium selago-lucidulum*"; Parish, "*Ophioglossum californicum* in Central California"; Clute, "The Round-leaved Maiden Hair"; Eaton, "Notes on Isoetes"; Taylor, "How and where Ferns grow in Southwest Georgia."

Journal of Mycology, March : — Morgan, "The Genus Gibellula"; Arthur, "Cultures of Uredineæ in 1904"; Kellerman and Ricker, "First Supplement to 'New Genera of Fungi published since the Year 1900,' with Citation and Original Descriptions"; Kellerman, "Notes from Mycological Literature — XIV."

Journal of the New York Botanical Garden, April: — Howe, "Some of the Coralline Seaweeds in the Museum"; Nash, "The Crested Orchid."

Journal of the New York Botanical Garden, May: — Britton, "Explorations in the Bahamas"; Cowell, "Report on Explorations in Panama."

Journal of the New York Botanical Garden, June: — MacDougal, "Botanical Explorations in Arizona, Sonora, California, and Baja California."

Journal of the New York Botanical Garden, July: — Murrill, "A Trip to Cuba"; Hollick, "The Preservation of Plants by Geologic Processes."

The Ohio Naturalist, April: — Claassen, "Key to the Liverworts recognized in the Sixth Edition of Gray's 'Manual of Botany'"; Smith, "Key to the Ohio Elms in the Winter Condition"; Gleason, "Notes from the Ohio State Herbarium — III"; Riddle, "Development of the Embryo-sac and Embryo of *Staphylia trifoliata*."

The Ohio Naturalist, May: — Schaffner, "The Nature of the Reduction Division and Related Phenomena"; Fischer, "A List of Ohio Plants with Compound Leaves"; York, "The Agar-agar and Paraffin Method for Imbedding Plant Tissues"; Cushman, "A few Ohio Desmids."

The Ohio Naturalist, June: — Development of the Embryo Sac and Embryo of *Batrachium longirostris*"; S[chaffner], "Leaf Expansion of Trees and Shrubs"; Schaffner, "Key to the Genera of Ohio Woody Plants based on Leaf and Twig Characters."

The Plant World, March: — Nash, "A Trip to the Inaguas;" Arthur, "On the Nomenclature of Fungi having Many Fruit-forms"; Streeter, "A Treasure Spot of Wild Flowers"; Wiegand, "The Biology of Buds and Twigs in Winter."

The Plant World, April: — Nash, "A Trip to the Inaguas (Conclusion)"; Arthur, "On the Nomenclature of Fungi having Many Fruit-forms (Conclusion)"; Bailey, "Early Wild Flowers"; Shaw, "Botanizing in British Columbia."

The Plant World, May: — Greene, "The Earliest Local Flora [Thalius, 1588]"; Beal, "The Gas Plant."

Rhodora, April: — Fernald and Knowlton, "*Draba incana* and its Allies in Northeastern America"; Woodward, "Some Plants Rare

or hitherto Unrecorded in Connecticut"; Harper, "Coastal-plain Plants in New England"; Terry, "*Hieracium murorum* in Massachusetts"; Meader, "*Actinella odorata* in Maine."

Rhodora, May:— Fernald, "The North American Species of Eriophorum — I"; Haberer, "Plants of Oneida County, N. Y., and Vicinity — I"; Collins, "*Chlorochytrium lemnæ* in America"; Terry, "*Dicksonia pilosiuscula* forma *schizophylla* in Vermont"; Churchill, "Three Plants New to the Flora of Vermont."

Rhodora, June: — Robinson, "Two Varieties of *Sisymbrium officinale* in America"; Gilman, "Two Ferns New to the Flora of Vermont"; Leavitt and Spalding, "Parthenogenesis in Antennaria"; Haberer, "Plants of Oneida County, N. Y., and Vicinity — I (Continued)"; Hervey, "*Silene conica* in New England"; Cushman, "A Contribution to the Desmid Flora of New Hampshire"; Tilton, "*Scrophularia leporella* at Willoughby."

Rhodora, July: — Chrysler, "Reforestation at Woods Hole, Mass. — a Study in Succession"; Fernald, "The North American Species of Eriophorum — II"; Setchell, "*Gymnogongrus torreyi*"; Woodward, "An Extension of Range of *Eatonia pubescens*"; Bartlett, "*Polygonum exsertum* in Massachusetts."

Torreya, April: — Harper, "Some Noteworthy Stations for *Pinus palustris*"; Murrill, "Terms applied to the Surface and Surface Appendages of Fungi"; King, "Experiment to show that the Absence of Light alone will prevent the Process of Photosynthesis"; Parish, "Birds and Mistletoe — a Correction"; Cockerell, "The Name Melampodium."

Torreya, May: — Schneider, "The Classification of Lichens"; Lloyd, "The Course of the Pollen Tube in Houstonia — a Preliminary Note"; — Reichling, "Contributions to the Recorded Fungus and Slime-mould Flora of Long Island"; Berry, "Three Cotyledons in Juglans"; Ellis, "A New Rosellinia [*R. bakeri*] from Nicaragua"; Underwood, "A Much-named Fern [*Microstaphyla moorei*].

Torreya, June: — Greene, "Some Ptelea Segregates"; Yatsu, "Cytological Differences between the Palmella and Filamentous Forms of Stigeocloneum"; Parish, "Flowering of *Yucca australis*"; Underwood, "*Botrychium silaifolium* Presl"; Eggleston, "*Amelanchier arguta*"; Taylor, "Nature's Engrafting"; Gilg, "A New Gentian from Bolivia"; Nash, "A Trio of Grasses New to the West Indies."

The first volume of the new series of "Contributions from the Gray Herbarium of Harvard University," extending from 1891 to 1903, has been completed by the recent issue of title page, index, errata, etc., compiled by Miss Day.

The following botanical papers are contained in vol. 19 of the *Transactions of the Kansas Academy of Science*: — Sayre, "Bibliography of the Loco Weed"; Speckman, "Dissemination and Germination of Seeds"; Schaffner, "Myxomycetes of Clay County, Kansas"; Crevecoeur, "Some Variations among some Kansas Wild Flowers"; Sayre, "Echinacea Roots"; Baker, "Notes on the Culture of Wild Flowers."

The recently issued *Sixteenth Annual Report of the Missouri Botanical Garden* contains the following botanical papers: — Hitchcock, "The Identification of Walter's Grasses"; Berger, "A Systematic Revision of the Genus Cereus"; Bush, "The North American Species of Fuirena," and "Two New Texas Tradescantias"; MacMenzie and Bush, "New Plants from Missouri"; Spaulding, "A Disease of Black Oaks caused by *Polyporus obtusus*"; von Schrenk, "Glassy Fir," "On the Occurrence of *Peronospora parasitica* on Cauliflower," and "Intumescences Formed as a Result of Chemical Stimulation"; Hedgcock, "A Disease of Cauliflower and Cabbage caused by Sclerotinia," and "A Disease of Cultivated Agaves due to Colletotrichum"; Life, "Vegetative Structure of Mesogloia"; Trelease, "Illustrations of a 'Strangling' Fig Tree"; and Harris, "The Dehiscence of Anthers by Apical Pores."

The Fifth Annual Report of the Michigan Academy of Science contains the following papers of botancial interest: — Beal, "Michigan Flora — Fern and Seed Plants Growing without Cultivation"; Chase, "Flora of Michigan — Diatomaceæ"; Bogue, "The Lichen Genus Physcia"; Beal, "How I know some of our Trees in Winter"; Clark, "The Limits of Difference in Specific and Subspecific Distinctions."

The opening fascicle (nos. 1–3) of *Montana Agricultural College Science Studies* contains: — Blankinship, "A Century of Botanical Explorations in Montana"; Blankinship, "Supplement to the Flora of Montana — Additions and Corrections," and Blankinship and Henshall, "Common Names of Montana Plants."

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